Recommendations of specific chemicals are based upon information on the manufacturer's label and performance in a limited number of trials. Because environmental conditions and methods of application by growers may vary widely, performance of the chemical will not always conform to the safety and pest control standards indicated by experimental data.

Recommendations for the use of agricultural chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by North Carolina Cooperative Extension nor discrimination against similar products or services not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before applying any chemical. For assistance, contact your county Cooperative Extension agent.

Some chemicals used for pest control are extremely toxic, whereas others are only moderately or slightly toxic. It is very important that people involved in the application of pesticides or exposed to them before, during, or after application take precautions to protect themselves. When appropriate, wear protective clothing and equipment as directed on the pesticide label, and observe all other directions for safe handling and application of the chemical. Make sure that anyone working with the chemicals or spray equipment knows and understands the potential hazards and has adequate protection.

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2018 COTTON INFORMATION

NC STATE EXTENSION

2018 COTTON INFORMATION

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Prepared by

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NC State Extension
College of Agriculture and Life Sciences
North Carolina State University

2018 Cotton Information is meant to help growers plan for the coming year and make management decisions based on the unique opportunities and challenges the year might bring. Web-based resources are available to supplement the information found here. These resources allow our specialists to make updated recommendations during the season.

Extension cotton portal—Timely production information updates, links to cotton information, and calendar of upcoming cotton events: **cotton.ces.ncsu.edu.** The NC Cotton Variety Performance Calculator can be found in the Extension cotton portal or directly at **trials.ces.ncsu.edu/cotton/.**

Facebook page—Join our cotton Facebook group for short cotton production updates and information. You can post pictures, experiences, and questions: **www.facebook.com/groups/344058599029946/?bookmark_t=group.**

Twitter notifications—Follow @NCCotton to receive notifications on your phone or computer when new information is added to these sites. You can set up a Twitter account at **twitter.com**.

CONTENTS

INDEX TO WEED MANAGEMENT IN COTTON

COUNTY EXTENSION PERSONNEL WORKING WITH COTTON

The following are the county North Carolina Cooperative Extension personnel with cotton responsibilities as of January 6, 2018. In some cases where a vacancy exists, the county Extension director's name is given.

COUNTY	NAME	CITY	TELEPHONE
Anson	Vacant	Wadesboro	704-694-2415
Beaufort	Rod Gurganus	Washington	252-946-0111
Bertie	Jarette Hurry	Windsor	252-794-5317
Bladen	Bruce McLean	Elizabethtown	910-862-4591
Camden	Austin Brown	Camden	252-331-7630
Carteret	Mike Carroll	Morehead	252-222-6352
Chowan	Matt Leary	Edenton	252-482-6585, x 107
Cleveland	Greg Traywick	Shelby	704-482-4365
Columbus	Michael Shaw	Whiteville	910-640-6605
Craven	Mike Carroll	New Bern	252-633-1477
Cumberland	Tyler Adams	Fayetteville	910-321-6875
Davidson	Troy Coggins	Lexington	336-242-2080
Duplin	Blake Sandlin	Kenansville	910-296-2143
Edgecombe	Art Bradley	Tarboro	252-641-7815
Gates	Paul Smith	Gatesville	252-357-1400
Greene	Roy Thagard	Snow Hill	252-747-5831
Halifax	Arthur Whitehead	Halifax	252-583-5161
Harnett	Brian Parrish	Lillington	910-893-7530
Hertford	Joshua Holland	Winton	252-358-7822
Hoke	Howard Wallace	Raeford	910-875-3461
Hyde	Andrea Gibbs	Swan Quarter	252-926-4488.
Iredell	Laura Elmore	Statesville	704-873-0507
Johnston	Tim Britton	Smithfield	919-989-5380
Jones	Jacob Morgan	Trenton	252-448-9621
Lee	Zach Taylor	Sanford	919-775-5624
Lenoir	Jacob Morgan	Kinston	252-527-2191
Martin	Lance Grimes	Williamston	252-789-4370
Montgomery	Brad Thompson	Troy	910-576-6011
Nash	Maryanna Bennett	Nashville	252-459-9810
Northampton	Craig Ellison	Jackson	252-534-2831
Onslow	Melissa Huffman	Jacksonville	910-455-5873
Pamlico	Daniel Simpson	Bayboro	252-745-4121
Pasquotank	Alton Wood Jr.	Elizabeth City	252-338-3954

COUNTY	NAME	CITY	TELEPHONE
Pender	Mark Seitz	Burgaw	910-259-1235
Perquimans	Dylan Lilley	Hertford	252-426-5428
Pitt	Lance Grimes	Greenville	252-902-1704
Richmond	Paige Burns	Rockingham	910-997-8255
Robeson	Mac Malloy	Lumberton	910-671-3276
Rowan	Morgan Watts	Salisbury	704-633-0571
Rutherford	Janice McGuinn	Rutherfordton	828-287-6010
Sampson	Della King	Clinton	910-592-7161
Scotland	Randy Wood	Laurinburg	910-277-2422
Stanly	Dustin Adcock	Albemarle	704-983-3987
Tyrrell	Vacant	Columbia	252-796-1581
Union	Vacant	Monroe	704-283-3801
Warren	Kelsey Lichtenwalner	Warrenton	252-257-3640
Washington	Vacant	Plymouth	252-793-2163
Wayne	Kevin Johnson	Goldsboro	919-731-1520
Wilson	Norman Harrell	Wilson	252-237-0111

1. 2018 COTTON COST OF PRODUCTION

S. Gary Bullen
Extension Associate, Farm Management—Agricultural and Resource Economics

COTTON BUDGETS

Information and Web links on the cotton program, outlook and situation, budgets, farm management, and more are available at the North Carolina State University Department of Agricultural and Resource Economics website:

ag-econ.ncsu.edu/extension/budgets

The budgets in Tables 1-1 through 1-3 represent costs and returns that are achieved by many growers in different regions of North Carolina using different production technologies. The budgets do not represent average costs and returns. Budgets are intended to be used as guides for calculating individual costs and returns.

Table 1-1. Cotton—TIDEWATER, NO-TILL—2018

Estimated Costs and Returns per Acre, 2018
900-Pound Yield

	Unit	Quantity	Price or Cost/Unit	Total/ Acre	Your Farm
1. GROSS RECEIPTS					
Cotton Lint	lb	900.00	$0.69	$621.00	
Cotton Seed	lb	1503.00	$0.09	$135.27	
Total Receipts:				**$756.27**	
2. VARIABLE COSTS					
Seed	thou	42.00	$2.11	$88.62	
Fertilizer					
30% N Solution	lb	164.00	$0.12	$19.68	
Phosphate (DAP 18-46-0)	lb	50.00	$0.24	$12.00	
Potash (0-0-60)	lb	48.00	$0.20	$9.60	
Boron	lb	3.00	$1.35	$4.05	
Sulfur	lb	10.00	$0.28	$2.80	
Lime (Prorated)	ton	0.33	$46.00	$15.18	
Pest Control (Weeds and Insects)	acre	1.00	$107.32	$107.32	
Growth Regulators and Defoliants	acre	1.00	$24.45	$24.45	
Scouting	acre	1.00	$16.00	$16.00	
Ginning	lb	900.00	$0.11	$94.50	
Crop Insurance	acre	1.00	$30.00	$30.00	
Tractor, Additional Machinery	acre	1.00	$70.03	$70.03	
Labor	hr	2.99	$11.27	$33.70	
Interest On Operating Capital	$	$193.00	5.0%	$9.69	
Total Variable Costs:				**$537.62**	
3. INCOME ABOVE VARIABLE COSTS				**$218.65**	
4. FIXED COSTS					
MACHINERY/OVERHEAD	acre	1.00	$121.42	$121.42	
TOTAL FIXED COSTS:				**$121.42**	
5. TOTAL COSTS				**$659.04**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT				**$97.23**	

BREAK-EVEN YIELD	***BREAK-EVEN PRICE***
Variable Costs: 603 lb Total Costs: 766 lb	Variable Costs: $0.45 Total Costs: $0.58

Note: This budget is for planning purposes only and does not include land rent.

Prepared by Derek Washburn, North Carolina State University, Department of Agricultural and Resource Economics.

Table 1-2. Cotton—CONVENTIONAL TILLAGE—2018

Estimated Costs and Returns per Acre, 2018
830-Pound Yield

	Unit	Quantity	Price Or Cost/Unit	Total/ Acre	Your Farm
1. GROSS RECEIPTS					
Cotton Lint	lb	830.00	$0.69	$572.70	
Cotton Seed	lb	1386.00	$0.09	$124.74	
Total Receipts:				**$697.44**	
2. VARIABLE COSTS					
Seed	thou	42.00	$2.11	$88.62	
Fertilizer:					
30% N. Sol.	lb	151.00	$0.12	$18.12	
Phosphate (DAP 18-46-0)	lb	46.00	$0.24	$11.04	
Potash (0-0-60)	lb	44.00	$0.20	$8.80	
Sulfur	lb	10.00	$0.28	$2.80	
Boron	lb	3.00	$1.35	$4.05	
Lime (Prorated)	ton	0.33	$46.00	$15.18	
Pest Control (Weeds and Insects)	acre	1.00	$83.20	$83.20	
Growth Regulators and Defoliants	acre	1.00	$23.85	$23.85	
Scouting	acre	1.00	$16.00	$16.00	
Ginning	lb	830.00	$0.11	$87.15	
Crop Insurance	acre	1.00	$30.00	$30.00	
Tractor, Additional Machinery	acre	1.00	$73.58	$73.58	
Labor	hr	3.44	$11.27	$38.77	
Interest On Operating Capital	$	$184.01	5.0%	$9.20	
Total Variable Costs:				**$510.36**	
3. INCOME ABOVE VARIABLE COSTS				**$187.08**	
4. FIXED COSTS					
MACHINERY/OVERHEAD	acre	1.00	$123.20	$123.20	
Total Fixed Costs:				**$123.20**	
5. TOTAL COSTS				**$633.56**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT				**$63.88**	

BREAK-EVEN YIELD	***BREAK-EVEN PRICE***
Variable Costs: 576 lb Total Costs: 742 lb	Variable Costs: $0.46 Total Costs: $0.61

Note: This budget is for planning purposes only and does not include land rent.

Prepared by Derek Washburn, North Carolina State University, Department of Agricultural and Resource Economics.

Table 1-3. Cotton—NO TILL—2018

Estimated Costs and Returns per Acre, 2018
830-Pound Yield

	Unit	Quantity	Price Or Cost/Unit	Total/ Acre	Your Farm
1. GROSS RECEIPTS					
Cotton Lint	lb	830.00	$0.69	$572.70	
Cotton Seed	lb	1386.00	$0.09	$124.74	
Total Receipts:				**$697.44**	
2. VARIABLE COSTS					
Seed	thou	151.00	$0.12	$18.12	
Fertilizer:		46.00	$0.24	$11.04	
30% N. Sol.	lb	44.00	$0.20	$8.80	
Phosphate (DAP 18-46-0)	lb	3.00	$1.35	$4.05	
Potash (0-0-60)	lb	10.00	$0.28	$2.80	
Sulfur	lb	0.33	$46.00	$15.18	
Boron	lb	1.00	$96.25	$96.25	
Lime (Prorated)	ton	1.00	$24.17	$24.17	
Pest Control (Weeds and Insects)	acre	1.00	$16.00	$16.00	
Growth Regulators and Defoliants	acre	830.00	$0.11	$87.15	
Scouting	acre	1.00	$30.00	$30.00	
Ginning	lb	1.00	$70.03	$70.03	
Crop Insurance	acre	2.99	$11.27	$33.70	
Tractor, Additional Machinery	acre	$186.38	5.0%	$9.32	
Labor	hr	3.44	$11.27	$38.77	
Interest On Operating Capital	$	$184.01	5.0%	$9.20	
Total Variable Costs:				**$515.22**	
3. INCOME ABOVE VARIABLE COSTS				**$182.22**	
4. FIXED COSTS					
MACHINERY/OVERHEAD	acre	1.00	$119.86	$119.86	
Total Fixed Costs:				**$119.86**	
5. TOTAL COSTS				**$635.08**	
6. NET RETURNS TO LAND, RISK, AND MANAGEMENT				**$62.36**	

BREAK-EVEN YIELD	***BREAK-EVEN PRICE***
Variable Costs: 582 lb Total Costs: 744 lb	Variable Costs: $0.47 Total Costs: $0.61

Note: This budget is for planning purposes only and does not include land rent.

Prepared by Derek Washburn, North Carolina State University, Department of Agricultural and Resource Economics.

2. THE COTTON PLANT

Keith L. Edmisten
Guy Collins
Cotton Extension Specialists—Crop and Soil Sciences

Successful cotton production depends on an integrated management strategy that recognizes and adapts to the unique characteristics of the crop. The development of vegetative growth and fruiting forms is highly related to temperature if adequate moisture is available. The relationship between cotton development and temperature is best described by DD-60s. The equation for determining DD-60s is:

(°F Max + °F Min Temp)/2 - 60 = DD-60s

For example, if today's high and low temperatures were 80°F and 60°F, then the formula would give this answer: (80°F + 60°F)/2 - 60 = 10 DD-60s.

Cotton will produce a node about every 50 DD-60s or approximately every three days if moisture is adequate. This rate of growth will slow once the plant begins to bloom and fill bolls.

PERENNIAL GROWTH HABIT

In its native habitat, cotton is a perennial that does not die in the fall. Instead, the plant becomes dormant during periods of drought and resumes growth with the return of favorable rainfall. This characteristic is partially responsible for cotton's reputation of being a dry-weather crop. During periods of drought in North Carolina, a cotton plant will continue to grow the most mature bolls and abscise (or drop) the remaining boll load. This trait enables cotton to produce some yield even during severe drought years.

Along with this favorable drought-avoidance trait comes the undesirable feature of regrowth and the harvesting problems regrowth may create. Unlike annual crops that die following seed production, cotton will continue growing until environmental conditions become unfavorable. This trait is shown when cotton continues adding leaves and unharvestable bolls until a killing frost occurs. This second growth presents some producers with defoliation challenges while inducing others to delay harvest in the hopes of realizing additional yield. The consistent and reliable heat needed to continue to contribute significantly to yield rarely occurs past the middle of October in North Carolina.

FRUITING

Another growth characteristic associated with cotton's perennial nature is its indeterminate fruiting habit. Rather than flowering during a distinct period following vegetative growth, cotton simultaneously produces vegetation and fruiting structures. A cotton fruit begins as a small flower bud or "square" that flowers about 21 days after it reaches the size of a pinhead (just visible to the naked eye). The new bloom is white the first day (pollination occurs on the first day) and turns red by the second day. Cotton normally will flower for up to eight weeks in North Carolina. This characteristic allows the crop to compensate partially for earlier periods of unfavorable conditions. However, this longer fruiting period requires continued attention to pest management and complicates harvest timing decisions.

Squares that bloom by about August 15 in the northern part of the state and about August 20 in the southern part of the state should have a reasonable chance of maturing. These bolls should be full-sized by about mid to late September if we have a reasonable chance to harvest them. A boll needs about two weeks of decent weather after it becomes full-sized to mature (increase in micronaire). It takes at least six weeks or 750 DD-60s after the last harvestable bolls are set before the crop can be terminated without reducing overall lint yield and quality. Nine hundred DD-60s are usually needed from white bloom until a boll is fully mature. Although maturity is minimal at 750 DD-60s, overall lint quality is not seriously affected because the relative proportion of bolls set last is usually small.

TROPICAL ORIGINS

The third distinguishing characteristic of cotton results from its tropical origins. Cotton is adapted to regions where temperatures range from warm to hot. Grown as an annual crop in the United States, it is often necessary to plant cotton before the onset of consistently favorable temperatures. While cotton struggles to emerge from the soil and grow, diseases, weeds, and insects adapted to our environment can damage the crop. When several pests are present simultaneously, especially when accompanied by chemical stress, crop development may be severely retarded. Earliness, normally our best indicator of high yields, strongly depends on favorable environmental conditions during the early season. Cool and wet conditions during the early part of the growing season adversely affect cotton development.

Cotton varieties grown in North Carolina are all day-length insensitive, unlike soybeans. Because of this insensitivity, only early varieties should be planted in the latter half of the planting period. Maturity is primarily related to how early the plant begins to produce fruiting branches, in other words, from which node the cotton initiates fruiting. Early varieties will start fruiting around the fourth or fifth node, while late varieties will start fruiting higher up the plant.

LINT QUALITY

The price received by cotton producers is determined by both the quantity and quality of the harvested lint. While the nonfood nature of cotton may persuade newcomers of the crop's tolerance of harvesting delays, experienced growers recognize the value of timely harvests that preserve the maximum lint quality. Lint exposed to wet weather will become discolored, a reason to discount the ginned lint. Because of cotton's prolonged fruiting habit, some weathering of lint exposed to the elements is unavoidable. Green leaves resulting from incomplete defoliation or excessive regrowth also can cause grade discounts. Growers should concentrate on developing a harvest preparation strategy that retains as much lint quality as possible. This strategy can increase a grower's net return by several cents per pound.

SUMMARY OF PLANT DEVELOPMENT

Seedling leaves, or cotyledons, appear on the day of cotton emergence. True leaves will appear seven to 10 days later. After 30 to 35 days of vegetative growth, the first square (flower bud) will be formed on a fruiting branch arising from the axil (node) of the fifth to seventh true leaf. This important event marks the visible beginning of reproductive growth. The plant will normally continue to produce additional fruiting branches in an orderly manner up the main stem. Fruiting branches are distinguished by their zigzag appearance where a leaf and flower bud are formed at each angle. Each fruiting branch may produce several squares. However, more than 90 percent of the harvestable bolls will be found at either the first or second position on a fruiting branch. When plant populations are high, 90 percent of the harvestable bolls may be found at the first position on the fruiting branch.

North Carolina cotton normally produces between 12 and 15 of these fruiting branches. Research in North Carolina indicates that bolls produced at the first position of fruiting branches arising from nodes six through 10 have a 50 to 70 percent chance of becoming harvestable bolls (assuming protection from insects). Boll-set at position one declines at higher fruiting branches. Bolls produced on fruiting branches arising from nodes 18 or higher have less than a 10 percent chance of finding their way into the picker basket. The same trend is followed at position two except that boll-set peaks at 20 to 30 percent at nodes six to 10 and then declines.

The progression of cotton fruiting can be followed by estimating the interval between the appearance of cotton flowers up the main stalk and out each fruiting branch. The vertical fruiting interval, or VFI (the interval between appearance of white flowers at position one on adjacent fruiting branches), is approximately three days (50 DD-60s). The horizontal fruiting interval, or HFI (the interval between appearance of white flowers at positions one and two on the same fruiting branch), is approximately six days (100 DD-60s). For example, in Figure 2-1, the boll closest to the stalk on the lower branch is about nine days older than the white bloom on the second position of the upper branch (three days up and six days out). The same principle can be used throughout most of the plant to map when and where boll loading occurs. Due to boll load, this relationship can begin to break down for nodes and fruiting sites developed following peak bloom.

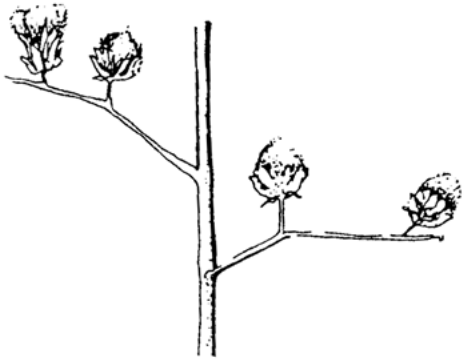

Figure 2.1. Section of a main stem showing two adjacent branches.

This process can be used to record and frequently identify the causes of fruit loss, such as water stress, insect damage, rank growth, cloudy weather, and prolonged periods of rain. Growers can then use this information in refining their management strategies.

PLANT MONITORING

Plant monitoring techniques, such as monitoring nodes above white bloom and plant mapping, have received a great deal of attention in the past few years. These techniques require a certain amount of time and energy but can tell us a lot about our cotton crop and how the crop should be managed. This section is divided into three subsections called prebloom, the bloom period, and the boll-opening period (postcutout).

Tables 2-1, 2-2, and 2-3 (at the end of this chapter) are examples of mapping sheets for use during prebloom, the bloom period, and the boll-opening period (postcutout), respectively. This plant monitoring method involves mapping only first positions of fruiting branches. Fruiting sites on vegetative branches and second or higher positions of fruiting branches are ignored.

PREBLOOM

Determining the Onset of Fruiting (Node of First Fruiting Branch)

When the cotton plant has about five or six true leaves, you should be able to detect pinhead squares in the terminal (top of the plant). By counting the number of main stem true leaves (ignore cotyledons) when a majority of the plants have a pinhead square, you can determine the node of the first fruiting branch. Well-managed early season varieties should begin fruiting on node five or six with an occasional plant fruiting at node four. Full-season varieties usually start fruiting about a node higher. As the plant grows larger, the leaves below the first fruiting branch will shed, and vegetative branches may develop from these lower nodes.

When determining the first fruiting node of older cotton, you will have to count the "notches" if the lower leaves have been shed. Do not count the cotyledon notches. The shedding of cotyledons will leave two notches directly across from each other just above the soil surface. The notches you are interested in are those that were formed by true leaves above the cotyledons.

Factors Affecting the Onset of Fruiting

Several factors alone or combined can influence the onset of fruiting. Low plant populations can lower the node of the first fruiting branch by as much as one node. High plant populations, cool temperatures (night temperatures below 60°F) during the weeks after emergence, thrips damage, or unusually high temperatures (nights remaining above 80°F) can raise the node of the first fruiting branch by as much as three nodes. Nitrogen stress also can raise the node of the first fruiting branch, although this change is rare because nitrogen requirements are low prior to fruiting, and preplant nitrogen applications almost always supply enough nitrogen to avoid delayed fruiting. If one or more of these factors have delayed squaring, then no visible square scar should be present. If visible square scars or black squares are present at nodes five or six, then the cotton is not delayed in squaring but is shedding squares.

In 1992, cool temperatures following planting raised the node of the first fruiting branch about 1.5 nodes. This change corresponded to about a five-day delay in maturity that resulted from slow growth during the cool period. Scout for pinhead square initiation to determine if the crop is developing on time.

Implications of Delayed Fruiting

Cotton that begins fruiting higher on the plant is more likely to grow rank, particularly if early squares are not retained. Retaining early squares and bolls becomes more important when cotton begins to fruit higher on the plant than normally. These fields should be monitored closely for fruit retention and the potential need for Pix applications to control plant height. Delayed fruiting increases the likelihood of a positive response to Pix. In addition, in-season nitrogen applications should be weighed carefully. Nitrogen application above recommended rates may further delay the crop and add to the potential for a rank crop.

Determining Fruit Retention

When the cotton plant has about five or six true leaves, you should be able to detect pinhead squares in the terminal (top of the plant). From this time through first bloom, it may be helpful to determine fruit retention using plant-mapping techniques. You should map plants from several areas of the field, and map at least 20 plants per field. The more plants you can map per field, the more accurately your mapping program will reflect the true fruiting pattern of the field. The percentage of fruit retention is determined by dividing the number of fruit by the number of fruiting sites. The resulting number is then multiplied by 100. For example, if you mapped 20 plants and came up with 75 fruits and 90 fruiting sites, the fruit retention would be 83 percent.

$$\% \text{ fruit retention} = \frac{\text{(number of fruit)}}{\text{(number of fruiting sites)}} \times 100$$

Example: $$\% \text{ fruit retention} = \frac{75}{90} \times 100 = 83\%$$

Causes of Early Square Shed

When squares are formed but then shed, a visible scar remains. Square shed prior to bloom can be caused by several factors, including insect damage; cloudy, cool weather; or water-saturated soils. However, it is often difficult to distinguish early season square shed due to insect damage from square shed due to weather conditions. Because weevils have been eradicated in North Carolina and plant bug damage is rare in our state, our fruit retention prior to bloom is usually very high. When square retention is lower than desired (below 80 to 90 percent), try to determine the possible cause. But don't be too quick to blame poor retention on plant bugs. Unnecessary spraying for plant bugs is not only a waste of money, but it will also kill beneficial insects that in turn may result in a higher likelihood that the cotton will need to be treated for (June) tobacco budworms. Unnecessary spraying also can cause aphid resistance.

Cool, cloudy weather (below 55°F at night) has been observed to cause square shed because of decreased photosynthesis. Water-saturated soils (often combined with cloudy weather) can cause square shed. Although drought conditions can cause shedding of small-to-medium-sized squares later in the season, square shed before bloom caused by drought stress is fairly rare. Other insects, including second-generation (June) tobacco budworms, can cause square loss, especially in the southern parts of the state. Never assume early square shed is entirely caused by weather conditions without first closely examining the insect situation in the field.

Significance of Early Fruit Retention

Square retention before bloom can have an effect on how the plant grows for the remainder of the season and on how the field should be managed. Fields with low early square retention are more likely to grow rank and have delayed maturity. Therefore, fields with low early square retention are more likely to respond to Pix applications. Because fields with low early square retention tend to grow rank, use nitrogen judiciously to minimize rank growth and the potential for boll rot. Scouting for insects should be intensified to avoid further excessive fruiting losses.

THE BLOOM PERIOD

Cotton normally blooms for seven or eight weeks. Stresses associated with drought, nematodes, and fertility can shorten the bloom period significantly. The bloom period also can be lengthened by poor fruit retention or excess nitrogen (with adequate rainfall). Plant mapping, as discussed under the Prebloom section, can be beneficial during the bloom period. In addition, monitoring the movement of first-position white blooms up the stalk during the bloom period gives us some insight into the condition of the crop.

Nodes Above White Bloom (NAWB)

Counting the nodes above white bloom (NAWB) is relatively easy during the bloom period. This technique involves locating the highest first-position white bloom on a plant and counting the nodes above that bloom. Each node above the highest first-position white bloom should be counted if the main stem leaf associated with the node is larger than a quarter. You will have to look for plants with a white bloom in the first position because not all plants have one at any given time.

Implications of NAWB

NAWB should be eight to ten at first bloom, depending on variety and growing conditions. NAWB at first bloom for short-season varieties that fruit on the fifth to sixth node normally will be at the lower end of this range, while full-season varieties usually will be at the higher end of the range. Environmental stress, such as drought, cool temperatures, or nitrogen deficiency, can result in a lower NAWB at first bloom. Poor fruit retention or excess nitrogen may result in a higher NAWB at first bloom. NAWB should begin to decrease after two weeks of bloom because of fruit load. If NAWB does not begin to decrease during the third week of bloom, fruit retention should be evaluated. An increase in NAWB during the season is usually caused by insect damage. Crops with a large NAWB may be suffering from poor fruit retention caused by insect damage. Under these situations, the crop will grow rank and be late maturing if ample moisture and nutrients are available. In crops with higher than normal NAWB at first bloom or crops in which NAWB does not begin to decrease during the third week of bloom, one can expect a strong response to mepiquat. On the other hand, mepiquat may not be needed in crops with low NAWB at first bloom or in crops in which NAWB decreases rapidly during the bloom period.

NAWB should continue to decrease through the remainder of the bloom period as the plant moves toward "flowering out the top." If NAWB is decreasing too rapidly, one should attempt to identify stresses and alleviate them if possible. The most common stresses that will cause a rapid decrease in NAWB are drought and nitrogen deficiency. When NAWB is lower than normal at first bloom or decreases more rapidly during bloom than desired because of drought stress, increasing the frequency of irrigation may be beneficial. Foliar urea applications have been shown to increase NAWB and yield when NAWB is lower than desired because of nitrogen deficiency.

When NAWB has reached five, the terminal has essentially ceased growth and cutout is imminent. Less than 2 percent of the yield is set after NAWB reaches four. Cutout occurs when NAWB reaches three or fewer.

When NAWB is higher than normal, look hard at insect-related fruit shed and consider mepiquat to control plant height.

When NAWB is lower than desired, avoid mepiquat use and attempt to alleviate any drought stress or nutrient deficiencies.

THE BOLL OPENING PERIOD (POSTCUTOUT)

Percent Open

Plant monitoring during the boll-opening period can help you schedule defoliations and determine whether boll openers are justified. Table 2-3 can be used to determine the percentage of open bolls. Cotton is almost always safe to defoliate at 60 percent open, but often it can be defoliated earlier if fruiting is compact (see chapter 12, "Cotton Defoliation"). Percent open is determined by counting the number of open and closed harvestable bolls on several plants in a field. The number of open bolls is divided by the total number of bolls (both open and unopen). For example, if you mapped 20 plants and came up with 195 open bolls and 105 closed bolls (300 total bolls), the percent open would be 65.

$$\%\text{ open} = \frac{\text{(number of open bolls)}}{\text{(total number of bolls)}} \times 100$$

Example: $$\%\text{ open} = \frac{195}{300} \times 100 = 65\%$$

Nodes Above Cracked Boll (NACB)

Bolls within four nodes above a cracked boll should be mature enough for defoliation in most fields. Counting the nodes above cracked boll (NACB) is a good technique to help schedule defoliation. This technique involves counting the nodes from the highest first-position boll that has cracked open enough that lint is visible up to the highest first-position boll you plan to harvest. This technique gives more focus to the unopened portion of the crop and is less likely to result in premature defoliation. When NACB reaches four, there will be essentially no yield loss due to defoliation in fields with normal plant densities. A yield loss of about 1 percent would be expected when defoliated at an NACB of five, and a yield loss of about 2 percent would be expected when defoliated at an NACB of six with normal planting densities. Fields with low plant populations (less than two plants per foot of row) will set more fruit on vegetative branches and outer positions of fruiting branches, and these fruit will be less mature. In these type fields, an NACB count of three might be a better estimate for timing defoliation.

Green Boll Counts

Deciding whether Prep is needed for boll-opening is often difficult. Counting the number of mature green bolls per foot of row is helpful in making this decision. In-depth information on the number of green bolls needed to justify Prep application is given in chapter 12, "Cotton Defoliation."

Table 2-1. Prebloom Plant-Monitoring Form

Field ______________________

Date ______________________

Plant Number	Height (inches)	Total Nodes	Node of First Fruiting Branch	Number of Fruiting Branches	First Position Squares Retained
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Average					

Table 2-2. Bloom Plant-Monitoring Form

Field ________________________

Date ________________________

Plant Number	Height (inches)	Nodes Above White Bloom	First Position Bolls Retained	Fruiting Branches Below White Bloom	First Position Squares Retained
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Average					

Table 2-3. Postcutout Plant-Monitoring Form

Field ________________________

Date ________________________

Plant Number	Height (inches)	Node Above Cracked Boll	First Position Unopened Bolls	Fruiting Branches Below Cracked Boll	First Position Open Bolls
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
Average					

3. DEVELOPING A MANAGEMENT STRATEGY: SHORT-SEASON TIMELINESS

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The key to successful cotton production in North Carolina is the adoption of a short-season management strategy. Cotton growers may equate a short-season management strategy with the recently overworked "earliness" philosophy. While in principle earliness is a worthwhile goal, particularly in a short-season management system, earliness alone may lead producers to adopt practices that unnecessarily limit yield and profit. Even at the northern margins of the Cotton Belt, there is sufficient time to consistently produce yields in excess of two bales per acre. "Timeliness" is the key component of a management strategy that is fluid enough to accomplish this yield level.

Earliness and timeliness frequently mean the same thing in North Carolina, although not always. There are few production practices that do not require some season-to-season and within-season modification to improve their effectiveness within a production system. For example, nitrogen fertilization must be adjusted for residue left by the preceding crop, as well as for the unique characteristics of the soil and environment currently encountered. Variety selection depends on soil type, planting date, and harvest scheduling, as well as yield and quality potential. The earliest variety may or may not be appropriate in a specific field. Plant-growth regulators help a producer achieve earlier harvest, but sometimes that earlier harvest is not possible due to time constraints, picker availability, or harvest schedule. The key to successful cotton management is adapting the strategy to the specific situation. There are five specific goals important to producing a profitable crop in a short-season production system.

1. MAXIMUM EARLY SEASON GROWTH

Cotton farmers and researchers alike recognize the yield benefits that result from rapid early season development. Strong emergence of healthy seedlings that establish a uniform stand is the foundation enabling maximum early season growth. Once a stand is established, vegetative growth should be promoted through the judicious use of cultivation, fertilizers, and agrichemicals.

2. STIMULATE EARLY FLOWERING

Early flowering follows maximum early season growth. Commercially desirable varieties raised in North Carolina normally produce their first fruiting branch when the plants have between five and seven true leaves. A fruiting branch produces squares, or flower buds, that may become harvestable bolls. Flowering is delayed when physiological, chemical, or insect-related stress retards square formation or causes square abscission (shed).

Examine cotton plants with five to seven true leaves and note whether small squares, sometimes referred to as pinhead or match-head squares, are present on the plant. If they are, then your cotton is developing properly. If they are not, then you may need to alter your management plans to increase square formation and retention. This situation may require you to apply Pix to reduce the likelihood of rank growth, delay nitrogen side-dressing, increase insect scouting and treatments to avoid further loss, and avoid overtop treatments with fluometuron (Cotoran or Meturon) or MSMA/DSMA. Over-the-top applications of Roundup to Roundup Ready cotton after the four-leaf stage can cause early fruit loss and delay maturity. Post-directed applications of Roundup to Roundup Ready cotton also can cause fruit loss if the application is made too high on the plant. Growers should carefully follow the Roundup label to avoid delays in maturity caused by Roundup applications.

3. PREVENT RANK GROWTH

Excessive vegetative or rank growth historically has been a common problem for cotton farmers, particularly in a rain belt like North Carolina. Problems associated with rank growth include (1) delayed maturity, (2) increased insect damage, (3) increased boll rot, (4) more difficult defoliation, and (5) decreased harvest efficiency. The indeterminate, perennial growth habit of cotton is partially responsible for this undesirable trait. Unlike determinate, annual crops such as corn and small grains, cotton will support vegetative and reproductive growth simultaneously. Early season growth is dominated by vegetative growth. Once flowering and boll loading begin, vegetative growth slows because bolls have preference over leaves and stems for available energy and nutrients. When cutout occurs or cotton blooms out the top, the plant's energy and nutrients from the leaves have been entirely directed to the bolls. Vegetative growth ceases until a sufficient number of bolls have matured enough to allow vegetative growth to resume. The development of cotton is a changing balancing act.

Rank growth occurs when this balancing act is disturbed and vegetative growth predominates over boll loading. The imbalance can happen in several ways. Abundant water and nitrogen accompanied by warm weather will support vigorous growth before bloom. As plant vigor and leaf area increase, sunlight available for photosynthesis lower in the plant canopy decreases. Individual bolls are supported by leaves growing nearby. The earliest squares and bolls that form at nodes five through seven are fed by leaves that may not photosynthesize sufficient energy to support fruit growth. The result of this increased shading and decreased available energy is square and boll shed. Square and boll shed also may result from insect damage and pesticide damage or other environmental stress, such as drought or nutrient deficiencies. Rank growth also can begin after the flowering starts. Whatever the cause, rank growth can snowball by reducing boll load and thereby increasing the potential energy available for further vegetative growth.

In the past, farmers were ill-equipped to control rank growth. The available solutions were to (1) plant on the sandiest drought-prone land, (2) withhold nitrogen, (3) avoid irrigation, and (4) chop the tops out of rank cotton. Fortunately, with the availability of mepiquat chloride or Pix, the judicious use of nitrogen, and timely insect control, we can largely avoid rank growth.

4. PROTECT INVESTMENTS FROM PESTS

To produce cotton profitably, pest control must be viewed as a wise investment, not another cost. Typically, a new grower may see that the weed, insect, and disease management costs comprise a large and seemingly excessive part of the production expenses. Therefore, a new producer may delay or avoid timely pest management. This delay is a serious mistake.

The tools available to minimize economic damage from pests are limited. Timeliness is the essence of effective pest management in cotton. Timely crop development is the first defense against pest damage. Perform those agronomic practices that promote cotton fruiting development. Cotton can better compete with pests if it is healthy and actively growing. Some pesticide applications are inevitable because of the poor competitiveness of this tropical crop during the early part of the season and the attractiveness of cotton to insects. The effectiveness of cotton pesticides is entirely dependent on timely application in a technically appropriate manner.

Veteran cotton producers can speak with experience about the field or crop that was lost because weeds, insects, or diseases overran the cotton.

5. HARVEST QUALITY COTTON

North Carolina cotton producers can expect some harvest delays because of rain and high humidity. In addition to delaying harvest, these environmental conditions can reduce lint quality and yield. Harvest delays also may result from the harvesting of other crops, particularly peanuts. Growers need to remember that these delays can, and frequently do, reduce the value of their cotton. Timely harvest will increase or maintain the value of an investment in cotton.

In many years there is a temptation for growers to delay defoliation in the hopes of increasing yields. Growers in North Carolina need to remember that we seldom have the type of weather needed to increase yields after the first week or two in October. Cotton left in the field not only suffers losses in reduced quality but also in reduced yield because lint falls off the plant. Losses exceeding 100 pounds of lint per acre over a six-week period have been observed in North Carolina, particularly in varieties with poor stormproof characteristics. In addition, days and hours suitable for harvest generally decline in the fall. As a result, gaining a week for potential added growth in late September or early October may delay the final harvest of the season by a much longer period.

4. PLANTING DECISIONS

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PLANTING DATE

In a short-season cotton production region, planting date has a large, direct effect on development, maturity, and harvested yield. Planting date also influences insect control, plant growth regulator, and defoliation strategies indirectly. Decisions on planting date should not be taken lightly.

Although cotton planting used to start as early as March in North Carolina in the past, there have been many developments that have caused us to shift the optimum planting dates to later in the year. These developments include varieties bred to be earlier, boll weevil eradication, *Bt* cotton, the loss of Temik for thrips control, improved seed treatments, and the availability of growth regulators to manage maturity. In addition, the high cost of seed due to the technology delivered through the seed has made replanting less desirable. Figure 4-1 shows the effect of planting date on cotton yields over a five-year period.

Careful analysis of the data presented in Figure 4-1 shows that yield response to planting date is not linear but strongly polynomial and that yields begin to drop to below early planting levels about 40 days after April 29, which would be after June 10. These data suggest the optimum planting date should be shifted later rather than earlier. Planning to complete planting by May 31 should provide a long planting period and a short "insurance" period should replanting be needed. Cotton planting should be completed by June 10 if full yield potential is desired. For crop insurance purposes, growers need to have cotton planted before May 25th.

While planting date is important, soil temperature during the first five to 10 days after planting also influences early season cotton health and development. Research conducted in other states has established a relationship between temperature during stand establishment and subsequent stand yield. These findings indicate that temperatures below 50°F in the seed zone can cause chilling injury. The cooler the temperature, the more severe the damage, and the damage is cumulative.

There are two distinct sensitive periods during seedling emergence. First, the cotton seed is sensitive to temperatures below 50°F when it is absorbing water to begin germination. The cotton seed can die if temperatures dip to 41°F. The second period of sensitivity is normally reached about two days after planting and may occur as the cotton seedling begins to grow.

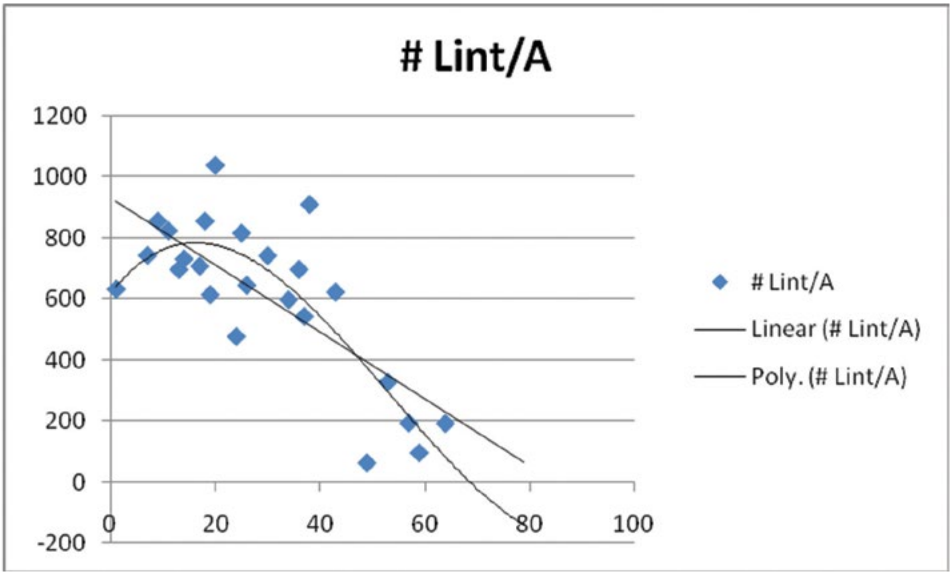

Figure 4-1. The effect of planting date on lint yield from April 29 over multiple years. (X axis is days after April 29.)

Temperatures below 50°F may either kill the seedling or cause growth retardation for weeks into the season. Many veteran cotton growers have observed the poor growth that occurs when recently planted cotton is subjected to cold temperatures.

Table 4-1. Relationship Between Predicted DD-60s and Planting Conditions

Predicted DD-60 accumulation for five days following planting	**Planting conditions**
10 or fewer	Very poor
11 to 15	Marginal
16 to 25	Adequate
25 to 50	Very good
More than 50	Excellent

Avoid planting cotton if the low temperature is predicted to be below 50°F for either of the two nights following planting.

SUGGESTED PLANTING DATES

Ideally, planting should proceed after April 15 when (1) the soil temperature has reached 65°F by 10:00 a.m. in a 3-inch-deep, moist, prepared seedbed and (2) when warm, dry weather is predicted for the next five to seven days. Unfortunately, it is not always possible to plant cotton in a timely fashion following this guideline. Temperatures above 70°F result in rapid germination, whereas germination is very slow at temperatures below 60°F. The risk associated with planting in cold soils is exacerbated under wet conditions. The relationship between predicted DD-60 accumulation for the five days following planting and planting conditions is shown in Table 4-1.

Normally, emergence will occur after 50 DD-60s have accumulated. Calculation of DD-60s is described in chapter 2, "The Cotton Plant."

PLANT POPULATION

Plant population has a profound influence on crop development. High plant populations (greater than three plants per foot on 38-inch rows) increase the percentage of the crop set at the first position of fruiting branches while reducing the total number of fruiting branches. This situation tends to shorten the boll-loading period compared to planting lower populations. Unfortunately, high plant populations decrease the cotton crop's ability to withstand drought stress.

The effect of plant population on final yield depends on rainfall patterns and crop/moisture relations. During those years when July and August rainfall exceeds 5 inches per month and the crop does not undergo prolonged drought stress, optimum yields can be achieved with plant populations varying from two to four plants per foot (28,000 to 55,000 plants per acre on 38-inch rows). However, in years when drought stress is pronounced, higher yields are achieved with plant populations of less than two plants per foot.

Choosing an appropriate cotton seeding rate is further complicated by an inherent weakness in cotton. Cotton cannot emerge through a thick soil crust. When cotton is planted deeper than ¾-inch and a surface crust forms following a packing rain, seedling emergence can be severely reduced. One response is to increase seedling rate, expecting normal seedling mortality. This strategy may backfire if seedling emergence is not hindered by a surface crust. A high emergence rate results in a plant population that cannot withstand drought stress.

A balance must be struck to achieve optimum yields, regardless of soil crusting characteristics and crop/moisture relations.

SEEDING RATE AND DEPTH GUIDELINE

Calibrate the planter to place four to six seeds per foot. Set the planter to place the seeds ½-inch to 1-inch deep depending on soil type, crusting potential, and moisture levels. Under most conditions, you will have an adequate plant population. If germination and emergence are excellent, your cotton will still have some ability to rebound following drought stress. Slightly adjusting seeding rates higher and planting shallower is generally recommended when planting in less than ideal conditions, especially for smaller seeded varieties.

REPLANTING DECISIONS

Nonuniform "skippy" cotton stands may be caused by poor seedling emergence, postemergence damping-off, hail damage, or insect damage. Growers are rightfully concerned that these stands may not be adequate to sustain high lint yields. The question "Should I replant?" rises from this concern. There is no simple answer to this question. However, several points should be considered before making a decision.

The effects of planting date on yield are well-known. The advantages of a more uniform stand must be weighed against the delay in maturity that results from cotton planted later. In addition, there is no guarantee that replanted cotton will emerge satisfactorily. Finally, if the skippy cotton was planted before May 10, it frequently can compensate with larger, more heavily fruited plants. This tendency is particularly true if midseason drought occurs.

No satisfactory rules have been set to guide you in replanting decisions. Some data from Georgia years ago suggested that if 50 percent of the planted area is occupied by skips of 3 feet or greater, then replanting may be justified. Experienced growers will attempt to work with a skippy stand rather than replant. If there are sufficient plants, work with what you have rather than replant. If the stand is unacceptable in many areas, try to replant only those areas.

If you are totally at a loss, ask for assistance from your county Cooperative Extension agent.

Finally, remember that a skippy cotton stand looks better at the end of the season than at the beginning.

5. VARIETY SELECTION

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Variety selection is one of the most important decisions a grower makes at the beginning of the crop year. There are several criteria for variety selection that may be important to a grower. How these criteria rank may vary from one grower to another, and the criteria may vary for the same grower from one field to the next depending on various factors such as weed pressure, soil types, planting date, and anticipated harvest schedules. Several criteria for variety selection are discussed below.

VARIETY SELECTION CRITERIA

Transgenic Traits

Most cotton produced in North Carolina has been genetically engineered to have an insect control package and an herbicide resistance package. The herbicide resistance package is the one of most concern to growers in variety selection. Glyphosate-tolerant varieties have been very popular in North Carolina, but now glyphosate-resistant weeds have emerged in many areas of the state. Glyphosate-resistant Palmer amaranth—and, to a lesser extent, glyphosate-resistant horseweed—have led many growers to select varieties with gene packages that allow the application of Liberty herbicide to help control these glyphosate-resistant weeds. LibertyLink cotton varieties and WideStrike cotton varieties are both tolerant to Liberty herbicide. Tolerance of varieties with the WideStrike trait to Liberty is not complete, and growers assume all risks associated with Liberty applications to WideStrike cotton. In contrast to LibertyLink cotton, which is highly tolerant of Liberty, some injury can be expected when Liberty is applied to WideStrike cotton. The injury is basically leaf burn and can range from very minor to rather significant. However, the injury is contact in nature, and the crop generally recovers. More information about weed control systems and varieties is available in chapter 10, "Weed Management in Cotton."

Varieties in the tables presented in this chapter with the designation "RF" are Roundup Flex varieties that allow over-the-top applications of glyphosate. Varieties with the designation "GL" allow over-the-top applications of glufosinate and glyphosate. Varieties with the designation "XF" allow over-the-top applications of glyphosate and glufosinate as well as labeled formulations of dicamba (see chapter 10). Varieties with the designation "W3FE" allow for over-the-top applications of Liberty, glyphosate, and labeled formulations of 2,4-D (see chapter 10).

The W in "WRF" also indicates that the variety has *Cry1A(2)* and *Cry1F* genes to produce *Bt* endotoxins that have high activity against all pest caterpillar species other than cutworm. The abbreviation *B2* in a variety name indicates that the variety has *Cry1A(2*) and *Cry2A(b)* genes to produce *Bt* endotoxins that have high activity against all pest caterpillar species other than cutworm. The T in "GLT" indicates that the variety has *Cry1ab* and a *Cry2ae* to produce *Bt* endotoxins. The P in "GLTP"indicates that the varieties have a third insect resistance gene, *VIP3a*. The designations B3 and W3 likewise indicate that the varieties have the *VIP3a* gene.

Monsanto received regulatory approval to offer Bollgard XtendFlex to farmers this growing season. Xtendflex cotton varieties have dicamba and glufosinate tolerance in addition to glyphosate tolerance. In addition, Dow AgroSciences also received regulatory approval to offer Enlist to farmers in 2017. Enlist varieties will have 2,4-D and glufosinate tolerance in addition to glyphosate tolerance. Growers trying these new technologies need to make sure to use approved low-volatile formulations of these herbicides and pay careful attention to potential drift problems and tank clean-out when using dicamba or 2,4-D (see chapter 10, "Weed Management in Cotton"). Auxin best-management training is required to use these two new technologies, and growers should strictly adhere to label requirements when using these technologies.

Yield Stability

Yield stability is the ability of a variety to perform well across various environments. Although it is tempting for a grower to put a lot of emphasis on the variety test nearest to their farm, this is not the best practice. We have consistently seen that the best predictor of how a variety will perform in the upcoming year is not how well it did at that particular location in the past year but how frequently it performed well compared to other varieties **averaged across all locations** in prior years. Some varieties tend to rank well only in favorable environments, while others tend to rank highly across all environments. In the absence of irrigation, growers need to select varieties that have performed well in favorable environments as well as under stress.

Maturity

Maturity is an indication of how long it will take from planting until harvest for a variety. Cotton variety maturity is often classified as early, medium, late, or full season. The cotton varieties we grow are day-neutral plants in that flowering is not initiated based on photoperiodism. Soybeans are day-length sensitive, and this is why later varieties of soybeans are recommended for late plantings. The opposite is true for cotton. Early varieties start fruiting at a lower node on the plant than later varieties. The typical first fruiting node for an early variety is node five, while a late-season or full-season variety might not start fruiting until node eight or nine. For this reason, plantings after the middle of May should be devoted to early or mid varieties in North Carolina. Later maturing varieties require very timely management, especially when planting later in the planting window.

Late-season varieties do offer some advantages compared to early-season varieties. Later varieties tend not to be negatively affected by stress as much as early varieties. Growers may want to lean toward midseason to late-season varieties when planting on sandy soils that are prone to drought stress if the cotton can be planted early. In general, later-season varieties tend to have better fiber quality than earlier varieties.

Fiber Quality

The price a grower receives can be positively or negatively affected by fiber quality. Fiber quality is discussed in more detail in chapter 16, "Cotton Classification." Fiber length, strength, and uniformity are heavily influenced by genetics and, to a much lesser extent, by environment. Of these, fiber length is most often the factor of concern with growers in North Carolina. Growers can usually avoid discounts for fiber length by selecting varieties with longer fiber length. Micronaire is influenced by a combination of or interaction between environment and genetics. High mike is most likely in cotton produced under stress, primarily drought stress. Growers should particularly avoid planting varieties that tend to have higher micronaire in fields that have a history of drought stress.

Stormproof

"Stormproof" is a term that indicates how tightly a variety holds lint over time. Research in North Carolina has shown that high winds and rainfall can cause losses, especially when high winds and rainfall occur simultaneously. Stormproof characteristics of a variety are usually expressed as poor, fair, good, or excellent. Varieties that are considered to have poor or fair stormproof ratings should be planted in fields that can be harvested in a timely manner. Fields that a grower expects to be harvested in a less timely manner should be devoted to varieties with good stormproof ratings. The flip side of the coin is that varieties with poor stormproof ratings tend to pick cleaner; therefore, growers may want to plant a portion of their acreage to these varieties if they can be harvested quickly. The important factor is to consider harvest schedule with variety selection and placement with regard to stormproof characteristics.

Leaf Hair

Varieties have different amounts of hairs (tricomes) on the plant. The leaf hair typical for a variety is often classified as smooth, semi-smooth, and hairy. Smooth leaf varieties tend to have better leaf grades when the cotton is classed (chapter 16). Desiccating cotton during defoliation can also lead to high (bad) leaf grades. It is particularly important to try to avoid desiccation of hairy leaf varieties, as the desiccated leaves will tend to adhere to the lint, resulting in poor leaf grades. On the other hand, hairy varieties do not appear to be as attractive to plant bugs.

OFFICIAL VARIETY TESTING DATA

The 2017 locations used for the Official Variety Test data presented here are from the research stations at Lewiston, Clayton, Plymouth, Rocky Mount, and Salisbury. The fiber quality data was not available at the time of publication due to a breakdown at the lab. The fiber quality results will be available on the web and on the NC Cotton Variety Performance Calculator (trials.ces.ncsu.edu/cotton/) as soon as the tests are completed.

Every variety has both strengths and weaknesses. The more experience we have with a variety, the better we can place it on the farm and manage it. The best way to manage risk on the farm associated with variety selection is to follow these principles:

- Use as much variety testing information as you can.
- Do not plant too much acreage to any one variety, especially varieties with only one year of data available.
- Use multiple varieties to avoid putting too many eggs in one basket.

In addition, the NC Cotton Variety Performance Calculator is an online resource that brings added value for producers in evaluating cotton variety performance, based on a wide array of selection criteria. This value-added resource was developed by Dr. Guy Collins and Dr. Keith Edmisten beginning in 2015, with technical expertise from Mr. Rob Ladd of NC State Information Technology. The calculator includes multi-year and multi-environment replicated data from the NC State Official Variety Trials and the NC On-Farm Cotton Variety Evaluation Program. These robust programs are strongly supported by the NCCPA, NCDA&CS, NC State CALS, seed companies, and Cotton Incorporated. Collectively, these programs provide producers with a complete platform from which to evaluate cotton varieties from all regions and soil types in North Carolina. A special thanks goes to our NC State county Extension agents, consultants, research stations, and cooperating growers for their participation and support of these programs. The NC Cotton Variety Performance Calculator can be found online:
trials.ces.ncsu.edu/cotton/select_trials/

Table 5-1A. Three-Year Statewide (North Carolina) Average Performance of OVT Cotton CONVENTIONAL Varieties—2015 through 2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
Seed Source Genetics UA 222	1040 **	43.6	38	38
Seed Source Genetics HQ 210 CT	1038 *	42.1	40	43
MEAN	**1039**	**42.9**	**39**	**40**
C.V. (%)	6			
BLSD (K=50)	97			
S.E.	27			

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 6 environments.

Table 5-1B. Three-Year Statewide (North Carolina) Average Performance of OVT Cotton TRANSGENIC Varieties—2015 through 2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
DP 1646 B2XF	1138 **	46.7	40	70
DP 1555 B2RF	1117 *	46.6	39	63
DP 1614 B2XF	1095 *	46.6	35	76
PHY 312 WRF	1091 *	45.2	37	77
DP 1639 B2XF	1072	46.4	38	65
PHY 444 WRF	1061	45.7	36	63
DP 1522 B2XF	1058	45.0	38	73
DP 1538 B2XF	1056	46.2	39	63
NG 3522 B2XF	1051	45.5	33	72
ST 5115 GLT	1049	44.9	37	64
ST 4848 GLT	1045	46.0	37	70
ST 6182 GLT	1043	48.1	38	66
DP 1553 B2XF	997	45.7	39	57
MEAN	**1067**	**46.0**	**37**	**68**
C.V. (%)	8			
BLSD (K=50)	51			
S.E.	20			

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 18 environments.

Table 5-2A. Two-Year Statewide (North Carolina) Average Performance of OVT Cotton CONVENTIONAL Varieties—2016 through 2017

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
DP 1538 B2XF	1324 **	46.5	47	36
Seed Source Genetics HQ2 10CT	1095	41.9	43	46
Seed Source Genetics UA 222	1055	43.5	43	41
UA 48	1010	40.2	42	43
MEAN	**1121**	**43.0**	**44**	**41**
C.V. (%)	11			
BLSD (K=50)	196			
S.E.	61			

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 4 environments.

Table 5-2B. Two-Year Statewide (North Carolina) Average Performance of OVT Cotton TRANSGENIC Varieties—2016 through 2017

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
DP 1646 B2XF	1237 **	45.9	44	69
DP 1555 B2RF	1215 *	45.9	42	61
PHY 312 WRF	1179 *	44.1	40	77
DP 1614 B2XF	1177	46.0	38	77
ST 5020 GLT	1172	43.8	39	66
PHY 444 WRF	1150	44.8	39	63
DP 1639 B2XF	1137	45.8	41	65
ST 5115 GLT	1129	43.9	40	59
DP 1538 B2XF	1126	45.5	44	59
DG 3526 B2XF	1124	46.1	40	67
DP 1522 B2XF	1120	44.2	41	72
ST 4848 GLT	1119	44.9	41	68
ST 6182 GLT	1113	47.6	41	64
NG 3522 B2XF	1104	44.6	35	71
DP 1553 B2XF	1042	45.0	41	55
MEAN	**1143**	**45.2**	**40**	**66**
C.V. (%)	7			
BLSD (K=50)	60			
S.E.	24			

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 12 environments.

Table 5-3A. Average Performance of Cotton Varieties Across Locations—CONVENTIONAL VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
PHY 312 WRF	1754 **	45.2	46	34
DP 1538 B2XF	1520 *	45.9	49	22
ST 4848 GLT	1481 *	45.6	47	34
UA 48	1293	40.1	43	33
Seed Source HQ210CT	1267	41.2	45	32
Seed Source Genetics UA222	1248	42.7	44	29
AT 558	955	41.7	43	32
MEAN	**1360**	**43.2**	**45**	**31**
C.V. (%)	10.3			
BLSD (K=50)	292			
S.E.	98.8			

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 2 environments.

Table 5-3B. Average Performance of Cotton Varieties Across Locations—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
DP 1555 B2RF	1414 **	45.6	42	56
PX 4A54 W3FE	1410 *	45.3	35	62
DP 1646 B2XF	1379 *	45.8	42	63
PHY 330 W3FE	1372 *	46.1	39	68
PX 4A57 W3FE	1368 *	46.9	33	64
PX 4A52W3FE	1364 *	44.9	35	62
PHY 300 W3FE	1362 *	46.0	38	63
CPS 1702 GLT	1356 *	44.1	37	59
PHY 312 WRF	1348 *	43.8	38	68
PHY 340 W3FE	1343 *	46.8	39	66
DP 1614 B2XF	1338 *	46.1	36	70
PX 4A62 W3FE	1324	45.3	36	58
ST 5517 GLTP	1316	42.9	39	48
PHY 444 WRF	1315	44.9	36	53
ST 5020 GLT	1305	43.6	36	60
ST 5115 GLT	1303	43.9	40	49
PX 3A96 W3FE	1303	43.1	38	60
PX 3A99 W3FE	1301	44.2	39	64
CROPLAN 9608 B3XF	1300	47.9	37	58
DP 1851 B3XF	1287	45.4	41	52
DP 1820 B3XF	1281	46.3	41	61
DP 1725 B2XF	1276	46.6	40	61
PX 3A82 W3FE	1274	44.7	35	66
DP 1840 B3XF	1268	43.9	40	51
NG 5711 B3XF	1267	43.7	39	48
ST 6182 GLT	1264	47.2	40	54
PX 5B76 W3FE	1250	43.4	40	64
MON 16R353 B3XF	1248	47.0	40	54
CROPLAN 3885 B2XF	1246	44.7	42	49
ST 4848 GLT	1242	44.4	39	60

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 7 environments.

continued

Table 5-3B. Average Performance of Cotton Varieties Across Locations—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
NG 4601 B2XF	1242	44.7	38	62
DG 3526 B2XF	1240	45.6	38	60
CPS 16214 B2XF	1240	43.4	37	67
DP 1522 B2XF	1239	43.9	40	63
DP 1538 B2XF	1236	45.0	44	51
NG 4545 B2XF	1234	43.0	41	61
DG 3605 B2XF	1232	45.1	39	55
PHY 490 W3FE	1231	44.4	39	58
DP 1639 B2XF	1231	45.3	40	56
DP 1553 B2XF	1225	44.5	41	46
NG 5007 B2XF	1220	44.0	42	59
CROPLAN 3475 B2XF	1219	42.8	34	66
AMX 1710 B2XF	1218	43.1	38	64
NG 3522 B2XF	1213	44.0	34	60
PX 5B73 W3FE	1212	44.0	37	55
PHY 450 W3FE	1192	42.9	38	58
ST 4949 GLT	1190	45.5	39	61
AMX 1715 B2XF	1153	42.3	36	65
PX 5A57 W3FE	1137	41.9	40	59
PX 2A28 W3FE	1121	43.6	34	60
MEAN	**1273**	**44.7**	**38**	**59**
C.V. (%)	7.1			
BLSD (K=50)	84			
S.E.	34.2			

**Highest yielder. *Not significantly different from highest yielder.
Based on data from 7 environments.

Table 5-4A. Average Performance of Cotton Varieties at Bertie County—CONVENTIONAL VARIETIES—2017

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
PHY 312 WRF	1879**	44.3	50	15
Seed Source HQ210CT	1547	41.1	50	26
ST 4848 GLT	1513	44.2	52	20
DP 1538 B2XF	1507	45.0	51	18
Seed Source Genetics UA222	1452	41.6	47	26
UA 48	1439	40.0	45	28
AT 558	1080	41.3	41	21
MEAN	**1488**	**42.5**	**48**	**22**
C.V. (%)	10			
LSD_10	154			
SEM	64			
Error d.f.	24			

**Highest yielder. *Not significantly different from highest yielder.

Table 5-4B. Average Performance of Cotton Varieties at Bertie County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
PHY 330 W3FE	1691**	47.4	46	45
DP 1646 B2XF	1669*	46.7	52	33
PHY 340 W3FE	1644*	47.6	48	48
PX 4A54 W3FE	1614*	46.3	44	44
PX 4A57 W3FE	1588*	48.1	37	48
PHY 300 W3F	1557	47.2	45	39
PX 4A52 W3FE	1555	46.4	44	41
DP 1614 B2XF	1511	47.7	46	37
PX 3A82 W3FE	1499	45.8	40	52
PX 5B76 W3FE	1496	44.7	50	41
DP 1555 B2RF	1493	46.7	50	27
PHY 450 W3FE	1489	44.4	43	40
PX5B73 W3FE	1485	45.7	45	34
ST 5517 GLTP	1485	43.8	46	22
PHY 312 WRF	1477	45.2	43	50
DP 1522 B2XF	1476	45.2	45	37
CPS 1702 GLT	1467	45.0	43	37
NG 5711 B3XF	1467	44.8	45	36
PX 3A99 W3FE	1463	46.3	46	43
DP 1725 B2XF	1460	47.7	47	25
CROPLAN 9608 B3XF	1457	47.2	45	33
ST 5115 GLT	1456	45.7	44	37
PHY 490 W3FE	1451	45.9	44	33
DP 1820 B3XF	1447	47.2	47	32
PX 3A96 W3FE	1444	44.6	48	46
PX 5A57 W3FE	1441	44.6	48	37
PHY 444 WRF	1441	45.5	43	26
PX 4A62 W3FE	1438	45.9	43	39
CPS 16214 B2XF	1434	45.0	42	50
NG 4601 B2XF	1431	46.9	40	37
CROPLAN 3885 B2XF	1427	46.7	49	24

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-4B. Average Performance of Cotton Varieties at Bertie County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
NG 4545 B2XF	1424	43.9	49	38
DP 1840 B3XF	1421	45.2	44	22
DP 1851 B3XF	1412	44.9	47	25
DG 3605 B2XF	1403	45.7	48	37
ST 4949 GLT	1399	47.8	47	37
ST 5020 GLT	1387	43.6	41	44
DP 1639 B2XF	1384	48.0	49	31
NG 5007 B2XF	1382	44.3	47	38
ST 6182 GLT	1382	48.3	49	32
ST 4848 GLT	1371	46.0	41	32
CROPLAN 3475 B2XF	1368	43.7	38	42
DP 1553 B2XF	1365	46.6	51	24
DP 1538 B2XF	1360	46.7	56	29
AMX 1710 B2XF	1357	44.6	41	40
NG 3522 B2XF	1348	45.3	40	32
MON 16R353 B3XF	1345	48.8	46	50
AMX 1715 B2XF	1342	42.7	43	43
PX 2A28 W3FE	1293	44.4	40	33
DG 3526 B2XF	1280	47.0	40	48
MEAN	**1450**	**45.9**	**45**	**37**
C.V. (%)	8			
LSD_10	103			
SEM	54			
Error d.f.	198			

**Highest yielder. *Not significantly different from highest yielder.

Table 5-5A. Average Performance of Cotton Varieties at Edgecombe County—CONVENTIONAL VARIETIES—2017

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
PHY 312 WRF	1629**	46.1	42	53
DP 1538 B2XF	1534*	46.7	46	25
ST 4848 GLT	1450*	47.1	43	49
UA 48	1147	40.1	41	38
Seed Source Genetics UA222	1045	43.8	42	33
Seed Source HQ210CT	987	41.3	40	39
AT 558	830	42.1	45	43
MEAN	**1232**	**43.9**	**42**	**40**
C.V. (%)	14			
LSD_10	181			
SEM	75			
Error d.f.	24			

**Highest yielder. *Not significantly different from highest yielder.

Table 5-5B. Average Performance of Cotton Varieties at Edgecombe County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
PX 4A54 W3FE	1613**	48.9	33	79
PHY 444 WRF	1612*	48.3	33	67
PX 4A52 W3FE	1560*	48.4	33	75
DP 1555 B2RF	1547*	48.4	35	73
ST 6182 GLT	1545*	49.1	35	75
PHY 300 W3F	1540*	48.4	36	78
PX 5B76 W3FE	1531	47.4	35	90
PX 4A62 W3FE	1530	48.8	30	78
PHY 340 W3FE	1527	50.0	36	82
NG 5007 B2XF	1525	47.5	40	80
CROPLAN 9608 B3XF	1519	50.4	35	81
PX 3A96 W3FE	1504	47.0	35	78
PHY 312 WRF	1500	46.3	36	83
ST 5020GLT	1497	46.3	37	78
PX 4A57 W3FE	1489	50.5	31	88
PX 3A99 W3FE	1485	47.5	34	82
PHY 330 W3FE	1483	48.8	38	96
DP 1851 B3XF	1483	48.0	36	62
DP 1538 B2XF	1483	47.4	39	74
NG 5711 B3XF	1482	45.3	35	75
CPS 1702 GLT	1480	46.5	34	81
DG 3526 B2XF	1462	49.4	36	76
DP 1646 B2XF	1453	47.6	37	85
PHY 490 W3FE	1436	47.2	36	77
CROPLAN 3885 B2XF	1436	47.4	37	71
AMX 1710 B2XF	1423	46.2	37	80
PX 5B73 W3FE	1414	46.4	36	82
ST 5115 GLT	1414	46.1	35	62
NG 3522 B2XF	1411	47.4	31	80
DP 1840 B3XF	1410	45.0	36	75
MON 16R353 B3XF	1405	49.1	35	75

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-5B. Average Performance of Cotton Varieties at Edgecombe County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
DP 1614 B2XF	1398	48.2	31	92
PX 3A82 W3FE	1397	47.2	30	76
DP 1553 B2XF	1390	46.1	33	67
ST 5517 GLTP	1379	44.8	35	78
PHY 450 W3FE	1378	45.7	35	68
DG 3605 B2XF	1365	47.6	37	75
ST 4949GLT	1363	49.2	34	81
NG 4545 B2XF	1363	44.4	39	85
DP 1522 B2XF	1359	45.9	37	87
CPS 16214 B2XF	1351	45.3	35	87
DP 1639 B2XF	1345	47.2	35	78
DP 1725 B2XF	1338	48.2	35	83
NG 4601 B2XF	1328	46.5	36	84
ST 4848 GLT	1320	47.1	36	74
PX 5A57 W3FE	1304	45.1	35	84
CROPLAN 3475 B2XF	1298	44.5	33	88
PX 2A28 W3FE	1296	45.9	31	71
DP 1820 B3XF	1278	48.1	34	92
AMX 1715 B2XF	1196	44.8	35	82
MEAN	**1433**	**47.3**	**35**	**79**
C.V. (%)	13			
LSD_10	80			
SEM	83			
Error d.f.	198			

**Highest yielder. *Not significantly different from highest yielder.

Table 5-6. Average Performance of Cotton Varieties at Johnston County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)
DP 1646 B2XF	1315**	45.7
DP 1555 B2RF	1247*	44.6
PX 4A54 W3FE	1230*	45.0
PX 3A82 W3FE	1228*	44.7
PHY 312 WRF	1216*	44.4
CROPLAN 9608 B3XF	1190	48.7
ST 5517 GLTP	1185	43.0
DG 3605 B2XF	1177	44.3
PX 4A62 W3FE	1170	44.9
ST 5020 GLT	1170	43.0
PHY 300 W3FE	1169	46.6
DP 1614 B2XF	1168	46.0
PX 5B73 W3FE	1165	44.6
PX 4A57 W3FE	1163	46.5
PHY 444 WRF	1159	44.7
PX 3A99 W3FE	1158	43.9
DP 1851 B3XF	1154	45.9
PX 3A96 W3FE	1135	43.1
PX 5B76 W3FE	1134	41.7
PX 4A52 W3FE	1127	43.4
NG 5007 B2XF	1125	44.2
ST 6182 GLT	1123	47.8
DP 1639 B2XF	1120	45.3
PHY 340 W3FE	1116	45.1
ST 5115 GLT	1113	43.5
PHY 330 W3FE	1108	45.9
MON 16R353 B3XF	1103	46.5
DP 1538 B2XF	1100	45.5
NG 5711 B3XF	1099	44.3
CROPLAN 3885 B2XF	1098	45.3
CPS 1702 GLT	1094	43.3
PHY 450 W3FE	1079	41.7

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-6. Average Performance of Cotton Varieties at Johnston County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**
NG 4601 B2XF	1072	44.9
DP 1820 B3XF	1069	46.7
NG 3522 B2XF	1068	43.7
DP 1840 B3XF	1063	44.7
PHY 490 W3FE	1058	42.6
DP 1522 B2XF	1049	44.1
DP 1553 B2XF	1030	44.0
ST 4848 GLT	1028	42.7
AMX 1710 B2XF	1028	43.7
DG 3526 B2XF	1024	46.1
CROPLAN 3475 B2XF	1016	42.2
DP 1725 B2XF	1012	45.8
NG 4545 B2XF	999	43.9
ST 4949 GLT	981	44.8
PX 5A57 W3FE	974	40.6
CPS 16214 B2XF	974	42.4
PX 2A28 W3FE	972	44.5
AMX 1715 B2XF	828	42.7
MEAN	**1104**	**44.5**
C.V. (%)	18	
LSD_10	104	
SEM	89	
Error d.f.	198	

**Highest yielder. *Not significantly different from highest yielder.

Table 5-7. Average Performance of Cotton Varieties at Scotland County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)
DP 1555 B2RF	1770**	45.1
DP 1725 B2XF	1729*	46.1
MON 16R353 B3XF	1700*	45.5
CPS 1702 GLT	1689*	42.5
NG 5711 B3XF	1662*	42.5
DP 1851 B3XF	1622*	44.5
DP 1820 B3XF	1613*	44.8
DP 1840 B3XF	1612*	42.9
CROPLAN 3885 B2XF	1587*	43.6
DP 1646 B2XF	1587*	44.5
NG 4601 B2XF	1574	43.7
PX 4A52 W3FE	1571	43.2
PX 3A99 W3FE	1567	42.6
PX 4A54 W3FE	1543	42.2
ST 5517 GLTP	1537	40.2
ST 4848 GLT	1533	43.0
PX 4A62 W3FE	1510	43.3
PX 4A57 W3FE	1502	44.5
DP 1553 B2XF	1499	42.7
PHY 312 WRF	1497	41.9
ST 4949 GLT	1495	43.3
CROPLAN 9608 B3XF	1489	45.0
PHY 444 WRF	1475	43.2
ST 5020 GLT	1469	42.3
AMX 1715 B2XF	1461	39.3
PHY 330 W3FE	1460	43.5
DP 1614 B2XF	1458	44.5
DP 1639 B2XF	1453	43.8
DG 3526 B2XF	1450	43.3
PX 3A96 W3FE	1450	39.8
PX 3A82 W3FE	1447	42.9
DP 1538 B2XF	1440	43.4

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-7. Average Performance of Cotton Varieties at Scotland County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**
NG 4545 B2XF	1439	41.7
PHY 490 W3FE	1437	42.2
DG 3605 B2XF	1435	43.5
DP 1522 B2XF	1435	42.2
ST 5115 GLT	1416	41.3
PHY 300 W3F	1399	43.3
NG 3522 B2XF	1383	42.0
CPS 16214 B2XF	1361	41.2
ST 6182 GLT	1344	45.2
PX 5A57 W3FE	1314	41.1
PHY 340 W3FE	1300	43.3
PHY 450 W3FE	1299	40.1
CROPLAN 3475 B2XF	1292	41.2
AMX 1710 B2XF	1276	40.4
PX 5B73 W3FE	1270	41.4
PX 2A28 W3FE	1237	41.5
NG 5007 B2XF	1234	41.7
PX 5B76 W3FE	1227	41.9
MEAN	**1471**	**42.8**
C.V. (%)	13	
LSD_10	189	
SEM	84	
Error d.f.	198	

**Highest yielder. *Not significantly different from highest yielder.

Table 5-8. Average Performance of Cotton Varieties at Washington County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
DP 1555 B2RF	1449**	43.4	59	42
CPS 1702 GLT	1389*	44.3	42	52
PX 4A62 W3FE	1387*	44.5	46	45
DP 1614 B2XF	1385*	44.1	44	55
PHY 340 W3FE	1377*	46.6	45	48
PHY 444 WRF	1371*	42.5	43	42
DP 1646 B2XF	1366*	44.0	51	50
ST 5115 GLT	1363*	42.7	51	38
PHY 330 W3FE	1353*	43.9	46	63
PHY 300 W3F	1343*	44.0	44	61
ST 5517 GLTP	1320*	41.9	50	36
DP 1553 B2XF	1319*	44.1	52	37
PX 4A54 W3FE	1308*	43.8	40	48
DP 1522 B2XF	1308*	43.2	49	51
PX 3A96 W3FE	1298*	42.6	45	40
DP 1725 B2XF	1296*	45.6	50	51
CPS 16214 B2XF	1255	42.2	42	59
DP 1820 B3XF	1253	44.3	54	41
ST 5020 GLT	1244	42.0	42	39
PHY 312 WRF	1242	41.1	47	56
CROPLAN 3475 B2XF	1227	41.1	37	57
PX 4A57 W3FE	1226	43.6	42	40
PX 4A52 W3FE	1222	43.0	43	56
CROPLAN 9608 B3XF	1211	45.7	41	45
ST 6182 GLT	1210	46.0	51	45
AMX 1710 B2XF	1199	41.2	47	55
DG 3526 B2XF	1195	44.7	47	52
PX 5B76 W3FE	1177	42.5	52	44
DP 1840 B3XF	1172	41.9	51	35
NG 4545 B2XF	1168	40.6	47	42
NG 5007 B2XF	1168	43.3	54	53

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-8. Average Performance of Cotton Varieties at Washington County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**	**Plant Height (inches)**	**Bolls Opened (%)**
AMX 1715 B2XF	1166	41.0	38	60
ST 4848 GLT	1165	42.4	54	52
DP 1538 B2XF	1164	43.1	52	41
PX 3A99 W3FE	1164	41.5	50	58
NG 5711 B3XF	1147	41.3	50	27
NG 4601 B2XF	1142	43.6	49	46
DP 1639 B2XF	1128	43.2	50	46
PX 3A82 W3FE	1102	42.6	48	57
DP 1851 B3XF	1098	42.9	54	44
DG 3605 B2XF	1083	43.5	45	29
MON 16R353 B3XF	1080	44.6	49	26
PHY 450 W3FE	1050	41.7	45	40
ST 4949 GLT	1009	42.7	45	47
CROPLAN 3885 B2XF	1003	42.3	54	26
PX 5A57 W3FE	997	39.7	50	37
PX 5B73 W3FE	993	41.5	43	34
NG 3522 B2XF	979	42.1	39	47
PX 2A28 W3FE	955	41.9	42	56
PHY 490 W3FE	946	42.7	49	46
MEAN	**1203**	**43.0**	**47**	**46**
C.V. (%)	14			
LSD_10	173			
SEM	75			
Error d.f.	198			

**Highest yielder. *Not significantly different from highest yielder.

Table 5-9. Average Performance of Cotton Varieties at Montgomery County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
CROPLAN 9608 B3XF	1062**	50.5	28	74
ST 5115 GLT	1054*	45.6	29	59
PX 4A57 W3FE	1050*	49.2	23	78
PX 4A54 W3FE	1048*	47.5	23	77
PHY 312 WRF	1038*	47.0	27	84
PHY 444 WRF	1028*	47.3	26	76
PHY 340 W3FE	1021*	49.7	26	86
PX 4A52 W3FE	1013*	47.2	22	76
PHY 330 W3FE	1009*	48.8	28	68
ST 6182 GLT	1008*	49.0	27	65
DP 1646 B2XF	1004*	47.8	28	82
MON 16R353 B3XF	1003*	47.8	29	66
DP 1851 B3XF	996*	48.3	29	78
DP 1820 B3XF	992*	48.0	30	77
DP 1555 B2RF	990*	46.4	26	83
PHY 300 W3F	987*	48.2	27	75
DP 1840 B3XF	980*	45.5	29	73
ST 5020 GLT	977*	45.5	27	79
CROPLAN 3885 B2XF	969	45.4	28	76
PX 4A62 W3FE	968	47.6	24	72
PHY 490 W3FE	964	46.8	27	74
DP 1538 B2XF	955	46.3	29	59
NG 5007 B2XF	951	45.1	27	64
DG 3526 B2XF	949	47.1	29	65
DP 1614 B2XF	945	47.8	24	95
NG 5711 B3XF	944	44.9	27	56
NG 3522 B2XF	931	44.5	27	83
PX 5B73 W3FE	926	47.3	26	71
PX 5B76 W3FE	925	45.3	25	81
NG 4545 B2XF	922	44.7	30	78
PX 3A82 W3FE	919	47.3	25	79

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-9. Average Performance of Cotton Varieties at Montgomery County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)	Plant Height (inches)	Bolls Opened (%)
DP 1639 B2XF	917	46.6	25	71
DG 3605 B2XF	916	47.5	28	80
PHY 450 W3FE	912	45.4	28	82
AMX 1715 B2XF	909	44.8	28	76
DP 1553 B2XF	907	45.5	29	56
PX 5A57 W3FE	904	43.9	28	79
NG 4601 B2XF	897	45.6	28	81
CPS 1702 GLT	895	44.3	30	66
ST 5517 GLTP	887	44.4	27	57
PX 3A99 W3FE	886	46.0	26	72
PX 2A28 W3FE	880	45.5	24	78
PX 3A96 W3FE	879	44.2	25	76
ST 4848 GLT	874	47.2	27	80
CPS 16214 B2XF	866	45.8	31	71
DP 1522 B2XF	864	44.9	29	76
AMX 1710 B2XF	852	43.7	28	81
ST 4949 GLT	847	46.9	29	80
CROPLAN 3475 B2XF	835	44.2	26	79
DP 1725 B2XF	822	47.2	27	84
MEAN	**946**	**46.5**	**27**	**75**
C.V. (%)	14			
LSD_10	88			
SEM	59			
Error d.f.	198			

**Highest yielder. *Not significantly different from highest yielder.

Table 5-10. Average Performance of Cotton Varieties at Rowan County—TRANSGENIC VARIETIES—2017

Variety or Brand Variety	Lint Yield (lb/acre)	Lint (%)
PX 4A57 W3FE	1558**	45.6
PHY 300 W3F	1538*	44.2
PX 4A54 W3FE	1512*	43.4
PX 4A52 W3FE	1501*	42.7
CROPLAN 3475 B2XF	1500*	42.6
DP 1614 B2XF	1500*	44.7
PHY 330 W3FE	1499*	44.1
CPS 1702 GLT	1478*	42.8
PHY 312 WRF	1467*	41.0
CPS 16214 B2XF	1436*	41.5
ST 5517GLTP	1421	42.0
PHY 340 W3FE	1419	45.0
PX 3A96 W3FE	1412	40.5
ST 4848 GLT	1402	42.3
DP 1555 B2RF	1400	44.7
ST 5020 GLT	1391	42.5
AMX 1710 B2XF	1388	42.1
PX 3A99 W3FE	1386	41.9
NG 3522 B2XF	1369	43.0
PHY 490 W3FE	1325	43.8
PX 3A82 W3FE	1325	42.6
NG 4545 B2XF	1324	41.7
DG 3526 B2XF	1322	41.3
DP 1820 B3XF	1315	44.7
ST 5115 GLT	1306	42.1
DP 1725 B2XF	1274	45.5
DP 1639 B2XF	1268	43.2
PX 4A62 W3FE	1267	42.3
PX 5B76 W3FE	1262	40.3
DP 1646 B2XF	1255	44.5
DG 3605 B2XF	1249	43.4
NG 4601 B2XF	1248	41.3

**Highest yielder. *Not significantly different from highest yielder.

continued

Table 5-10. Average Performance of Cotton Varieties at Rowan County—TRANSGENIC VARIETIES—2017 (continued)

Variety or Brand Variety	**Lint Yield (lb/acre)**	**Lint (%)**
DP 1851 B3XF	1240	43.6
ST 6182 GLT	1236	45.2
ST 4949 GLT	1234	44.0
PX 5B73 W3FE	1228	41.1
DP 1840 B3XF	1220	42.5
PX 2A28 W3FE	1212	41.5
CROPLAN 3885 B2XF	1204	42.0
DP 1522 B2XF	1183	42.0
CROPLAN 9608 B3XF	1169	47.5
AMX 1715 B2XF	1168	40.6
NG 5007 B2XF	1154	41.9
DP 1538 B2XF	1152	42.8
PHY 450 W3FE	1139	41.4
PHY 444 WRF	1117	42.5
MON 16R353 B3XF	1103	46.4
NG 5711 B3XF	1070	42.8
DP 1553 B2XF	1065	42.5
PX 5A57 W3FE	1021	38.1
MEAN	**1305**	**42.8**
C.V. (%)	12	
LSD_10	125	
SEM	68	
Error d.f.	198	

**Highest yielder. *Not significantly different from highest yielder.

6. COTTON SEED QUALITY AND PLANTING DECISIONS

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A uniform stand of healthy, vigorous seedlings is essential if growers are to achieve the yields and quality needed for profitable crop production. It is important for growers to plant high quality seed of varieties adapted to their farm situations, management styles, and intended market uses.

Cotton yield and quality depend upon the seedlings established in the spring; therefore, timely and uniform emergence is critical. However, obtaining adequate stands is not always easy. The failure of seeds to germinate or the failure of seedlings to survive the initial few weeks of growth can be caused by several factors, many of which can be managed by cotton producers.

PLANTING CONDITIONS

Cotton seeds are extremely sensitive to cool, wet soils during the early phases of germination and seedling growth. Avoid planting if heavy packing rains are expected, especially during periods of cool temperatures. If the stress is severe, germination can be delayed or may not occur. Young, tender seedlings also may be damaged or killed if exposed to prolonged periods of cool, wet conditions.

Growers should not be tempted to plant cotton when cool, wet weather is expected. Planting under these conditions can lead to poor stands and may result in the need to replant. Chilling injury is most likely from the time the seed imbibes water and for the next two days as the radical emerges. Growers may want to cease planting two days prior to a predicted wet and cool spell. Chilling injury can result in seedling death, poor seedling development, J-rooting, and tap root abortion. The abortion of the tap root can decrease the ability of the plant to perform well in dry periods later in the season.

SEED QUALITY AND THE COTTON COOL TEST

High quality cotton seeds are those seed lots with high germination and vigor potential. Most growers are familiar with standard germination, which is a measure of the seed's ability to produce a normal, healthy seedling when conditions are ideal. For cotton seed, standard germination tests are conducted under ideal germinating conditions at approximately 86°F. However, most North Carolina growers plant cotton long before soils warm to 86°F. This standard germination is the germination percentage you will find on the seed bag.

The potential of a cotton seed to germinate in cool, wet soils depends upon the vigor level of the seed. Seed vigor is a measure of the seed's ability to produce a normal, healthy seedling under a wide range of conditions. Several laboratory stress tests have been developed to estimate the vigor level and field performance potential of seed lots planted under less than ideal conditions. For cotton, there is a test known as the cool-germination test or cool test. In this test, instead of planting the seeds in ideal germinating conditions (86°F), the seeds are planted and evaluated for growth at 64.5°F. This cool temperature places stress on the seed, and only high-vigor seeds will germinate and produce seedlings with normal growth patterns.

The cool conditions used in this test are usually more closely related to field conditions than the standard warm germination test. This circumstance is especially true when planting early in the season or planting no-till. Studies have shown that high-vigor seeds germinate faster and seedlings develop more rapidly, thus avoiding many of the pathogens that cause seedling diseases.

The results of the cool test are not printed on the seed tag. However, this information is often available from the seed dealer. You can also check for this information with the seed company if the dealer does not have the information using the lot number. Small differences in cool-test results from one company to another may not be very meaningful. Company procedures for performing the cool test may vary slightly.

In addition, on-farm research conducted from 2015 to 2017 has illustrated that seed size may also be a predictor of relative seedling vigor. When planting into ideal conditions, excellent emergence can occur with essentially all seed sizes; however, smaller seed are clearly more sensitive to such factors as deep planting, crusting, and cool wet conditions. And smaller seeds may require replanting more often than larger seeded varieties when planting into adverse conditions. Seed size is expressed as the number of seeds per pound of seed: the lower the number, the larger the seed. Seed size is either explicitly printed on the bag or can be calculated by information on the bag. Some varieties are inherently smaller seeded than others, but seed size for any variety can change from year to year and varies among lot numbers. In general, seed sizes ranging from 3,000 to 4,000 seeds per pound are considered to be large seeded varieties, 4,000 to 5,000 seeds per pound are medium sized, and greater than 5,000 seeds per pound are considered to be small seeded varieties.

INTERPRETING COTTON COOL-TEST VALUES

It is the responsibility of the grower to understand what the cool-test values mean. There is a significant vigor difference between seed lots with 85 percent and 60 percent cool-germination test results. But this fact does not mean that an 85 percent stand and a 60 percent stand will result from these two seed lots. It means the seed lot with an 85 percent cool-test result is likely to perform better in the field if stress conditions occur than is the lot with a 60 percent cool-test result. The low-vigor lot may do just as well as the high-vigor lot if both are planted when there is little or no stress. Likewise, if the lot with 85 percent cool germination is planted and soil temperatures immediately become extremely cool and wet, germination and seedling survival may never get near the 85 percent mark.

If growers have several seed lots, but the lots differ in cool-test results, growers should take care that the seed lots with lower cool-test readings should be planted under as ideal conditions as possible.

SEED TREATMENTS

Planting cotton seed in early spring when temperatures can vary dramatically is one reason cotton seedling emergence fluctuates during any given season and from year to year. Seed companies know that one way to maximize emergence of cotton seedlings is to treat the seeds with both protective and systemic fungicides. Seed treatment chemistry has improved dramatically in recent years. Growers should refer to the *Seed and Seedling Disease* section in chapter 9, "Disease Management in Cotton," for information about additional fungicide treatment at planting.

SEED PERFORMANCE COMPLAINTS

The North Carolina General Assembly passed a law in 1998 to help resolve seed performance complaints outside court. Growers who purchase seeds that fail to perform as labeled (for example, poor germination, weed seeds present, or mislabeled variety) may file a complaint with the Commissioner of Agriculture to have his or her seed complaint investigated by the Seed Board. Details on filing a complaint can be found in *Handling Seed Complaints*, AG-596, available from county Cooperative Extension centers or from the North Carolina Department of Agriculture and Consumer Services (NCDA&CS).

7. FERTILIZATION

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A good cotton-fertilization program begins with regular soil testing. Soil-test results are the most accurate and economical way to determine the fertilizer and lime needs of cotton. Although small amounts of nutrients are removed from the field at harvest, cotton requires high availability of nutrients, particularly late in the season. A good liming program usually supplies adequate calcium (Ca) and magnesium (Mg); many soils can meet the demand for phosphorus (P) and most micronutrients without annual fertilizer applications. Soil-test results can let you know when additions of these nutrients are required and when they are not.

For example, 80 percent of the more than 64,000 soil samples submitted to the NCDA&CS laboratory in FY 2015 for cotton were either high or very high in phosphorus. These fields would very likely not need additional phosphorus for five to eight years. In addition, 64 percent of the samples were also high or very high in potassium (K).

Cotton is very sensitive to deficiencies of nitrogen (N), potassium (K), sulfur (S), and boron (B). These nutrients can be removed by leaching rains, especially in sandy soils. Of these elements, potassium is least subject to leaching, and its availability can be determined from a routine soil-test sample. Sulfur levels are included in NCDA&CS soil-test reports, but while the presence of sufficient S in a sample indicates response to additional S inputs is unlikely, a low S soil test merits further consideration. Sulfur typically leaches downward from a sandy topsoil and accumulates in underlying layers with more clay. Sufficient S for adequate plant growth could still be present if this underlying clay layer is within 18 inches of the surface; however, this subsoil layer is rarely sampled. Recommended rates of nitrogen, sulfur, and boron are based on long-term field trials over a wide range of conditions. Annual applications of these nutrients are usually recommended for most soils. On soils subject to leaching, two or more applications may be required to improve fertilizer efficiency and ensure adequate availability throughout the growing season. Typical nutrient deficiency symptoms can be seen at the following website, although actual problem diagnosis should be based on soil and plant laboratory analyses: deficiencies.soil.ncsu.edu/.

Fall or early winter is the best time to collect soil samples (September to November if you are sampling for nematodes at the same time). This schedule allows plenty of time to get the soil-test report back and to plan your fertilization and liming program before the busy planting season. In the coastal plain, sample every two to three years. In the piedmont, sampling every three to four years is adequate. Consult your county Cooperative Extension center, NCDA&CS agronomist, or local fertilizer dealer for details on sampling procedures.

SOIL ACIDITY AND LIMING

Of the crops grown in North Carolina, cotton is among the most sensitive to soil acidity. Marked growth and yield increases have repeatedly occurred when fields are properly limed. When the soil pH drops below 5.5, aluminum and manganese dissolve from soil clays and can severely decrease root elongation, as well as reduce plant growth. Such a condition puts additional stress on cotton because stunted roots don't reach as much water or nutrients. Look for "J-shaped" taproots, and collect separate subsoil samples to confirm this situation. Acidity also interferes with the availability and uptake of phosphorus, potassium, calcium, and magnesium. Poor nutrient uptake results in fewer and smaller bolls with poor lint quality.

The optimum pH for cotton ranges from 5.8 to 6.5 for mineral soils. On organic and mineral-organic soils, a target pH of 5.0 and 5.5 is suggested. We have paid too little attention to this requirement. In recent years, soil pH has become a major yield-limiting factor for cotton production in North Carolina. In FY 2015, 24 percent of the NCDA&CS soil-test results for cotton fields with mineral soils were below a pH of 5.8; over half of all mineral soils tested require lime. Many of these fields will be limed, and others were organic or mineral-organic soils with target pH less than 6.0, but excess soil acidity continues to be one of our largest yield-limiting factors (Figure 7-1).

The amount of lime required for optimum cotton production varies with soil texture, pH, organic

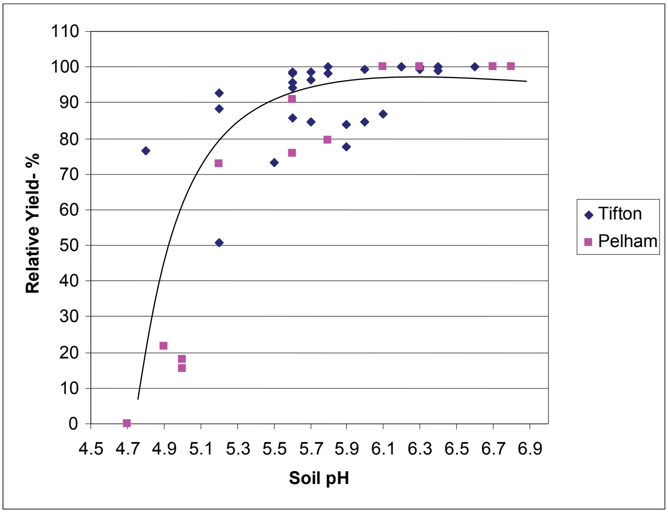

Figure 7-1. Relative yield of cotton as affected by soil pH in the top 0 – 15 cm soil. *Data are taken from field experiments in Georgia (Gascho and Parker, 2001, Agronomy Journal 93:1305-1315).*

matter content, soil minerals, and animal waste application history. Lime rate can be determined only through periodic soil testing to document both soil pH and residual soil acidity ("Ac" on the NCDA&CS soil test.) The recommended amount of lime should be applied several months before planting to allow time for it to dissolve and react with the acidic components of the soil. However, lime applied just before planting is much more effective than no lime applied at all. If possible, mix lime thoroughly with the soil to speed the reaction. For more information on soil acidity and liming, see SoilFacts publication AGW-439-50, *Soil Acidity and Liming for Agricultural Soils* (content.ces.ncsu.edu/soil-acidity-and-liming-for-agricultural-soils). This publication also describes how to evaluate alternative lime sources such as industrial slags.

NITROGEN FERTILIZATION

Nitrogen fertilization practices strongly affect growth and lint yield of cotton. Apply too little nitrogen, and yields drop sharply. On the other hand, apply too much nitrogen, or apply it at the wrong time, and plants will be rank, slow to fruit, more attractive to insect pests, late to mature, more difficult to cover with crop-protection chemicals, quick to develop boll rot, more troublesome and expensive to defoliate and control regrowth, and more likely to have grade reductions from bark.

Nitrogen Rate

The recommended rate of nitrogen ranges from 30 to 80 pounds per acre for rain fed crops (20 to 25 percent higher for irrigated crops). The best rate for a particular field depends on soil texture, the previous crop, expected rainfall patterns or irrigation, and grower experience in that field. Without knowledge of the field and of the specific management practices used, it is difficult to give specific recommendations, but some guidelines are available.

Uptake studies across the Cotton Belt suggest that cotton needs about 60 pounds of nitrogen per acre per bale of lint produced. Why are the recommended rates so much lower? Numerous on-farm nitrogen-rate studies throughout North Carolina show that unfertilized soils can supply 40 to 100 pounds of available nitrogen from organic matter, subsoil storage, and rainfall. Soil nitrogen reserves are generally highest on organic or mineral-organic soils and lowest on deep, well-drained sands. A good crop of soybeans or peanuts will supply an additional 20 to 30 pounds of nitrogen per acre. When soil nitrogen reserves are included, the recommended rates are consistent with a range of total available nitrogen from 110 to 170 pounds per acre following peanuts or soybeans, or from 90 to 140 pounds per acre following other crops.

Realistic yield expectations (RYE) are estimates of the yield potential (average of the best three out of five years) of a soil series under a high level of management. In conjunction with a nitrogen factor (for cotton this factor ranges from 0.03 to 0.12 pounds of nitrogen per pound of lint yield), RYE values can be used to estimate total nitrogen needs for a specific field. For example, a Norfolk soil has a RYE value of 875 pounds of lint per acre and a nitrogen factor of 0.09; thus, the calculated nitrogen rate is as follows:

875 pounds of lint per acre × 0.09 pounds N per pound of lint = 79 pounds N per acre

The nitrogen factor varies with residual nitrogen, available water-holding capacity of the soil, and management. In general, as any of these factors increase, the efficiency of nitrogen use increases, and associated nitrogen factor for the site decreases. Thus, organic and mineral-organic soils, with high residual nitrogen and available water-holding capacity, require low nitrogen factors ranging from 0.03 to 0.065, while deep sands, with low residual nitrogen and low available water-holding capacity, require nitrogen factors ranging from 0.07 to 0.12. Loamy soils require intermediate nitrogen factors ranging from 0.065 to 0.10. More information on realistic yield expectations is available via the Internet at nutrients.soil.ncsu.edu/yields or from your county Extension center.

Deficiency

Nitrogen deficiency symptoms first appear on the lower leaves. The leaves become a pale yellowish-green, fading with age, first to hues of yellow, then variously tinted shades of red, and finally brown as they dry up and are prematurely shed. Deficient plants are stunted and generally unthrifty in appearance, and fruit-set is poor.

If a deficiency develops, nitrogen can be applied to the soil until the second or third week of bloom or the last week of July. Beyond that point, soil applications become questionable. Foliar applications can increase yields at this stage of crop growth when plants are deficient (see the "Foliar Fertilization" and "Monitoring Plant Nutritional Status" sections). If extended rainfall leaches nitrogen out of the rooting zone after final application but before the second week of bloom, nitrogen should be replaced. Replacement N rates generally should not exceed 30 pounds per acre.

Timing

Timing is important for cotton. Unlike crops such as corn and tobacco, cotton takes up only a small portion of the nitrogen before flower buds (squares) begin to set (Figure 7-2). About 45 days after emergence, nutrient uptake begins to increase rapidly until it reaches a prolonged peak about two weeks after first bloom, when the processes of flower production, boll filling, and boll maturation create a heavy demand for nutrients. Frequently, all the nitrogen is applied early in the season, or even at planting. While this practice may be the most convenient means of application, it makes little sense in North Carolina due to unpredictable, leaching rains that can occur prior to nitrogen peak demands. Leaching losses during this period will need to be accounted for and replaced to attain optimum yield. Heavy nitrogen applications early in the season also can lead to excessive vegetative growth, smaller and more compact root systems, and reduced early square retention.

Cotton needs only 20 to 25 pounds of nitrogen per acre to get the plant through side-dress time. If the crop is following peanuts or soybeans, no initial nitrogen may be required. If rains were predictable, the best time to side-dress would be just before first bloom. However, because you can't always count on rains at this time, it is safer to side-dress two to three weeks after first

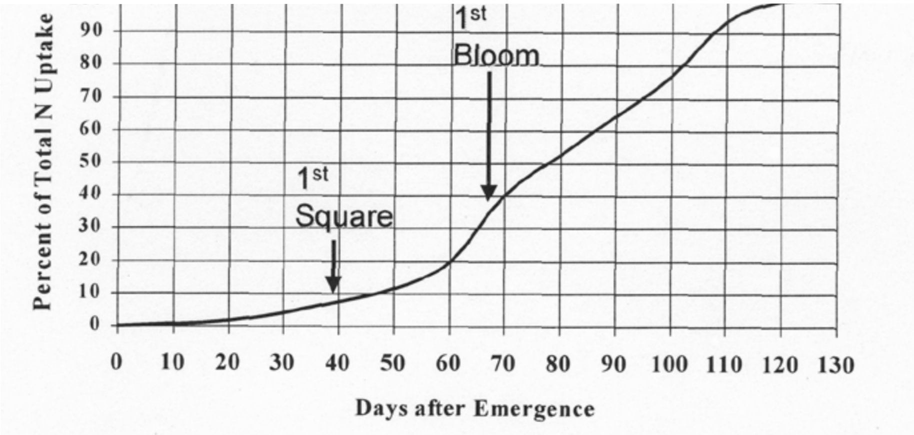

Figure 7-2. Timing of N uptake by cotton. Side-dress two to three weeks after first square should provide adequate N to sustain increased needs during the reproductive phase***.***

square to ensure that adequate nitrogen is available during the early-bloom period. On deep, sandy soils subject to rapid leaching, the side-dress nitrogen can be split, with half applied about four weeks after emergence and the remainder in three to four weeks.

Sources

Of the many nitrogen sources available for cotton fertilization, no one source has proven to be superior to others. Nitrogen solutions, ammonium nitrate, ammonium sulfate, urea, and anhydrous ammonia are most frequently used because of their high analysis. Sodium nitrate and calcium nitrate can be used, but have no proven benefit over ammonium-type fertilizers and cost more per pound of nitrogen applied. Conversion of ammonium forms to nitrate occurs very rapidly under warm, moist conditions. Fertilizer amendments and slow release N forms that attempt to reduce these rates of N transformations in order to reduce N losses are available, but their efficacy when used with cotton in the Southeast is not well established. The choice should be based on price, convenience, and availability of equipment. Nitrogen solutions are very convenient and exhibit little volatile loss when dribbled beside the row, even without cultivation. Urea is also a suitable nitrogen source, but surface-applications should be lightly incorporated on light, sandy soils. High humidity can make this source sticky and difficult to handle. Anhydrous ammonia is a very economical source of nitrogen, but requires specialized handling equipment and has not been widely available during recent years. The best results with N solutions, anhydrous ammonia, and granular urea or ammonium sulfate are obtained when side-dress applications are knifed-in about the time of first square. Take care to avoid root pruning, but don't place nitrogen out of reach of developing roots.

Nitrogen, Mepiquat Chloride, and Irrigation

The potential to reduce vegetative growth with the growth regulator mepiquat chloride has led some growers to increase nitrogen rates with the hope of increasing yields. On-farm tests in North Carolina consistently show that cotton yield response to nitrogen is not affected by mepiquat chloride applications. Higher than recommended nitrogen rates are not justified just because mepiquat chloride will be applied. Furthermore, where excessive rates of nitrogen are used and soil moisture is good, mepiquat chloride will not adequately control rank growth at labeled rates.

When irrigated, cotton yield potential on some soils can approach three bales. Higher nitrogen rates (90 to 120 pounds of nitrogen per acre) may be justified in these situations. When high nitrogen rates are planned for irrigated cotton, split the nitrogen applications to provide the bulk of the nitrogen as flowering begins. Plan to use mepiquat chloride to help control vegetative growth, but be aware that primary control of rank growth depends on maintaining high square retention and a heavy fruit load.

PHOSPHORUS, POTASSIUM, AND SULFUR

Adequate supplies of phosphorus and potassium are critical for proper plant nutrition. A good soil-testing program will help alert you to potential problems before they occur.

Phosphorus deficiencies are rare and usually associated with low pH. Plants appear darker green than normal, growth rate is slow, and plants may appear stunted. Treatments to correct phosphorus deficiency seldom prove effective, so placement in the root zone before planting is essential. Plants deficient in phosphorus produce fewer and slower-maturing bolls (see "Starter Fertilizers").

The symptoms of potassium deficiency can be very pronounced and first appear on the older leaves as a yellowish-white mottling. The mottling changes to a light yellowish-green, and yellow spots appear between veins. The centers of these spots die, and numerous brown specks appear at the leaf top, around the margin, and between the veins. The tip and the margin of the leaf break down first and curl downward. As this physiological breakdown progresses, the whole leaf becomes reddish-brown, dies, and is shed prematurely. The premature shedding of leaves contributes to dwarfed and immature bolls.

Throughout most of the state, potassium deficiency symptoms are rare and occur primarily on the plant's lower leaves, indicating improper preplant fertilization, in-season leaching losses, or root damage. Although potassium is retained by soils more strongly than nitrogen, it can be lost through leaching and may need replacing; K, however, can accumulate in the subsoil, and these supplies can be available to deep-rooted cotton. Growers managing soils with high leaching potential should seriously consider split applications of potash, applying half at planting and the other half at the time of lay-by nitrogen if possible. When warranted, prompt replacement is important, especially early in the season. Approximately 25 to 30 pounds per acre of potash should correct most leaching losses. Where deficiencies from leaching are likely, side-dress applications of potassium have frequently solved the problem. Applications of foliar potassium (such as potassium nitrate) at midbloom on potassium-deficient cotton can increase yields. Routine application of foliar K is not recommended because it has been shown to reduce yields in some cases where adequate K was already available. The best way to determine whether

K deficiency exists is with a plant tissue sample (see below, "Plant Monitoring and Foliar Fertilization").

In recent years, potassium deficiency symptoms have appeared in the upper part of the plant. In some cases, soil potassium levels appear to be high, but the plants are unable to obtain adequate potassium. In these cases, foliar potassium fertilization has improved yield and quality. At the present time, these symptoms have been associated with four factors:

1. The use of very high-yielding, determinate-type cultivars that set a heavy fruit load over a very short period.
2. Soils that "fix" potassium in nonavailable forms.
3. An unidentified disease.
4. Mild to moderate drought stress following heavy fruit set. Symptoms are most common in parts of California and the mid-South.

A few cases of upper plant-deficiency symptoms have occurred in on-farm tests and experimental plots in North Carolina where (1) subsoil potassium levels were extremely low and short- to midseason cultivars were planted or (2) soils contained significant amounts of 2:1 clay minerals such as vermiculite or montmorillonite. Soil surveys from most NC coastal plain counties have soils with taxonomic class names that begin with "Clayey, mixed" (including Bayboro, Bethera, Bladen, Cape Fear, Craven, Dogue, Gritney, Leaf, Lenoir, Roanoke, Wahee), which indicate these soils have such "mixed mineralogy." Even though soil-test levels at the surface may be adequate, deficiency symptoms may still develop; plants will likely respond to foliar applications of potassium. Annual applications to build soil potassium throughout the root zone will eventually correct these problems.

A two-bale cotton crop will take up 20 to 30 pounds of sulfur. Some sulfur is supplied by the decomposition of crop residues and organic matter, and some is supplied by rainfall. In recent years, sulfur deficiencies have become more common in row crops with the decline in industrial emissions of sulfur dioxide and the increased use of higher analysis materials and bulk blends containing less incidental sulfur. Sulfate-sulfur, the major form of sulfur taken up by plants, is mobile in most soils. Deficiencies are most likely to occur in highly leached, deep sandy soils with low organic matter content; depth to subsoil clay in these soils is usually greater than 18 inches from the surface. Sulfur accumulates in the subsoil. If sufficient sulfur is present in the subsoil and root growth is not restricted, older plants can take up enough for normal development. Additional sulfur may still be needed for early growth. Low pH in the subsoil can decrease availability of accumulated sulfur, particularly in red clays. For more information on sulfur, see SoilFacts publication AG-439-63, *Sulfur Fertilization of North Carolina Crops* (content.ces.ncsu.edu/sulfur-fertilization-of-north-carolina-crops).

Sulfur and nitrogen reactions in the plant are interrelated, and deficiency symptoms for the two nutrients are sometimes confused. Deficiency symptoms of both nutrients appear as general leaf yellowing. However, nitrogen is mobile within the plant, and its deficiency symptoms first appear on the lower leaves. Sulfur is relatively immobile, and deficiency symptoms first appear on new leaves. In cotton, persistent yellowing of new leaves and reddening of the petioles are typical sulfur-deficiency symptoms. In severe cases, the whole plant may become yellow. Both nitrogen and sulfur deficiencies may be present. When attempting to correct the deficiency, it is important to diagnose the problem correctly. Plant analysis is recommended because visual symptoms are difficult to interpret. If sulfur is lacking, the addition of nitrogen will not correct the problem. Soil application of sulfur appears more effective than foliar treatments for correcting deficiencies. Early detection is critical because treatments after flowering begins have not increased yields in most cases.

As a general rule, annual applications of 10 to 20 pounds of sulfur per acre are suggested. Additional sulfur probably will not be needed if cotton follows peanuts that received gypsum (land plaster). A variety of fertilizer materials contain sulfur (see Table 7-1). Ammonium sulfate, potassium sulfate, magnesium sulfate, sulfate of potash-magnesium, or granular and pelletized gypsum can be included in dry blends as a sulfur source, or applied in a separate application. Elemental sulfur can also be used, but the sulfur must first be oxidized by soil organisms to the sulfate form; sulfate sources are likely to be better choices. Because of this need for oxidation, elemental sulfur should be finely ground and applied early in the season to allow time for conversion to sulfate. There is increasing interest in adding 3 to 5 pounds of sulfur per acre in starter fertilizers. This practice can ensure adequate early season sulfur, but additional sulfur should be included in side-dress materials, especially on leachable, sandy soils. Sulfur-containing nitrogen solutions are now available in most areas. However, depending on the rate of nitrogen applied, the sulfur content of these solutions may not be adequate to provide sufficient sulfur for cotton without supplemental applications.

Table 7-1. Sources of Sulfur in Fertilizer Materials

	Nutrient Content	
Materials	**Percent Sulfur**	**Percent Other**
Ammonium sulfate	24	21 (N)
Potassium sulfate	18	50 (K_2O)
Magnesium sulfate	14	10 (Mg)
Sulfate of potash-magnesia	22	22 (K_2O) + 11% (Mg)
Gypsum (land plaster)	17 to 20	22 (Ca)
Sulfur-containing nitrogen solutions	3 to 5	24 (N)
Elemental sulfur	88 to 100	–

LIMING TO SUPPLY CALCIUM AND MAGNESIUM

Lime does more than raise soil pH. It is also the primary source of calcium and magnesium for cotton. Dolomitic lime supplies both calcium and magnesium, while calcitic lime supplies only calcium. Cotton has relatively high calcium and magnesium requirements. A two-bale crop will take up 60 pounds of calcium and 23 pounds of magnesium, with 4 pounds of calcium and 7 pounds of magnesium actually removed in seed and lint. Calcitic lime may be used if soil tests show that no magnesium is needed.

Calcium deficiencies are seldom seen because acidity (low pH) and aluminum toxicity usually limit growth first. The magnesium content of soils is usually less than that of calcium because less magnesium is added, more magnesium is removed, and it is more leachable than calcium. Magnesium deficiencies are most likely to occur on highly leached, sandy, low-organic-matter soils. Heavy applications of land plaster or potassium applications can also result in magnesium deficiencies. In cotton, magnesium deficiency appears first on the lower leaves as an intense yellowing between the major veins. In severe cases, and sometimes in cool soils, a purplish-red color develops around the leaf margins and between veins, while the veins maintain their dark-green color. Leaves shed prematurely. Late in the season, this color may be confused with the orange and red colors caused by normal aging of leaves. If magnesium is deficient, but it is not desirable to raise soil pH by adding dolomitic lime, then a source such as magnesium sulfate (10% Mg) or sulfate of potash magnesium (0-0-22, 11% Mg) can be applied at a rate to supply 20 to 30 pounds of magnesium per acre.

MICRONUTRIENTS

Boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) are necessary for plant growth, although the quantities needed are small. Specifically, boron, copper, zinc, and manganese should be of most concern to North Carolina cotton growers.

Boron

Boron is needed throughout the life of a cotton plant, but adequate supplies are especially crucial during flowering and boll development. Boron occurs in the soil as an uncharged molecule (boric acid) and leaches readily. Boron that is held by the soil is associated primarily with organic matter and is released as the organic matter decomposes. Dry weather can trigger a temporary deficiency as organic matter decomposition slows. Also, dry weather slows root growth and limits boron uptake. Thus, cotton grown on well-drained, sandy, low-organic-matter soils is more prone to boron deficiencies, especially in years of high rainfall or drought. Deficiencies can sometimes be induced by a soil pH greater than 6.5 or a heavy lime application in the recent past. The most pronounced boron deficiency symptoms include:

- Abnormal shedding of squares and young bolls.
- Ruptures at the base of squares or blooms.
- Dark-green rings on leaf petioles accompanied by discoloration of the pith under the rings.
- Death of the terminal bud and shortened internodes near the top of the plant, resulting in a dwarfed and many-branched plant.
- Mature bolls that are small, deformed, and do not fluff normally.

In many cases, the first real indication of a problem may be excessive growth. A close look at the plant will usually reveal abnormal fruit shed as the reason for this problem. If plants are not carefully monitored, the problem may not be noticed until harvest reveals an unexpectedly poor response to nitrogen and potassium applications.

The actual uptake requirement of boron by a two-bale cotton crop is about 0.2 pound per acre. Because boron is essential to successful production and availability is difficult to assess, annual application of boron to cotton is strongly recommended. Boron can be applied to the soil or foliage. The suggested rate of soil application is 1 pound of actual boron per acre broadcast before or during seedbed preparation, or 0.2 to 0.4 pound of actual boron per acre if a borated fertilizer is banded. Manufactured fertilizers containing boron or granular borate in dry blends can be purchased. Preplant applications are most effective for soils with limited leaching potential. For foliar applications, enough boron should be supplied to account for uptake inefficiencies and to offset leaching losses. A good general recommendation is to use 0.5 pound per acre of actual boron applied at early bloom or 0.25 pound per acre at early bloom and another 0.25 pound per acre about two weeks later.

Foliar applications allow placement of boron on the crop during peak demand. Some of the applied material will be taken into the plant and the remainder washed into the soil. Once inside the leaf, boron moves very little. This lack of movement means that new, untreated tissue can be deficient in boron unless boron is supplied by the root system.

The recommended rates of boron for foliar application will provide for the immediate needs of the plant and some residual to build soil reserves. This residual supplies the root system as long as the boron remains in the root zone. On deep, sandy soils, split foliar applications ensure availability during the critical bloom and boll-filling periods. Soluble boron sources are generally compatible with mepiquat chloride and most insecticides if enough water is used to dissolve the compound.

Copper, Manganese, and Zinc

Deficiencies of copper, manganese, and zinc are seldom seen in cotton. Determine applications of these elements based on soil-test reports. A soil-test index value less than 25 for any of these three micronutrients means that cotton may respond to an application, especially if the values are below 10 to 15. At present, the NCDA&CS Agronomic Division soil-testing laboratory prints a dollar sign ($) in the recommendation box if the soil level is low for sensitive crops, but there is no strong evidence that cotton is sensitive and will respond to additions of that element.

When in doubt, 2 pounds per acre of copper for mineral soils (4 pounds per acre for mineral-organic and 6 pounds per acre for organic), 6 pounds per acre of zinc, or 10 pounds per acre of manganese can be applied to increase the soil levels sufficiently so that micronutrients will not limit yields. Other crops in the rotation may benefit from the application. Be sure to read the note accompanying the soil-test report, which gives valuable information about micronutrient use. A zero printed in the recommendation block for any of the micronutrients means that the soil's level is adequate.

The above suggested rates should be broadcast and soil incorporated. You also may consider banding 3 pounds per acre of either manganese or zinc near the seed (3 to 4 inches on the side and 2 to 3 inches below) with the mixed fertilizer. Foliar sprays of copper, manganese, and zinc may be applied in emergency situations when the deficiency is discovered after the crop has been planted. Suggested foliar rates of manganese and zinc are 0.5 pound per acre; for copper, 0.25 pound per acre; follow label directions. Because the range between micronutrient deficiency and toxicity is quite narrow, it is important to be sure that application equipment is accurately calibrated.

Some common sources of copper, manganese, and zinc are listed in Table 7-2, and possible uses or application methods are shown in Table 7-3. In general, sulfate or chelated materials are recommended for foliar treatment of established plants or for soil application where pH values exceed 6.5. Oxides and oxy-sulfate materials are less soluble and require some time to react

Table 7-2. Micronutrient Sources, Concentrations, and Relative Cost

Micronutrient Source	Content (percent elemental)			Relative Cost per Pound
	Copper	Zinc	Manganese	
Oxide	50 or 75	70 to 80	25 to 28	Least costly
Oxy-sulfate	55			Intermediate cost
Sulfate	25	36	25 to 28	Moderate cost
Chelate	8 to 13	10 to 14	10 to 21	Most costly

Table 7-3. Suitability of Micronutrient Sources for Selected Uses

Used in	Micronutrient Source and Suitability			
	Oxides	Oxy-sulfates	Sulfates	Complexes or Chelates[1]
Fluid fertilizers[2]	Satisfactory in suspensions only	Satisfactory in suspensions only	Somewhat satisfactory	Satisfactory
30% nitrogen solutions	Difficult to dissolve	Difficult to dissolve	Difficult to dissolve	Usually satisfactory
Dry blends[3]	Usually satisfactory	Usually satisfactory	Usually satisfactory	Seldom used
Manufactured fertilizer	Satisfactory	Satisfactory		Not used
Water solution sprayed for soil application	Not satisfactory			Satisfactory
Foliar sprays[4]	Not satisfactory		Usually satisfactory	Satisfactory

[1] Often the label suggests a rate that is not adequate.
[2] Usually works in clear solutions; satisfactory in suspension fertilizer.
[3] Pulverized (finely ground) product should be bonded to fertilizer granules with a small amount of nitrogen solution or diesel fuel. Granular forms work well.
[4] May cause some foliar burn. Best to use low rates and make at least two applications about two weeks apart.

with the soil. These granular forms are commonly available for blending into preplant broadcast applications of NPK fertilizers. They are suitable for supplying micronutrients to the following crop and for building soil-test levels for later crops. Premium-grade fertilizers containing a mixture of micronutrients are available. Read the analysis tag to make sure the fertilizer will supply enough of the micronutrient in question to truly correct a soil deficiency. Also, compare prices because the cost of a premium-grade fertilizer may be more than the cost of a regular-grade fertilizer plus an application of the individual micronutrient needed.

FOLIAR FERTILIZATION

Recent studies have proven that foliar-applied nutrients such as urea nitrogen, potassium, and certain micronutrients can be absorbed through the leaf. The amounts of nutrients absorbed will not meet the full daily demands for these nutrients, but can supplement the soil-supplied nutrients. Under most conditions, the soil supplies adequate levels of nutrients. Foliar fertilization is expected to increase yields only when deficiencies occur. Deficiencies may result from improper fertilization, leaching of mobile nutrients by heavy rains, drought, or insect and disease stresses that damage root systems. Some researchers have observed that foliar nitrogen application may occasionally "stick a few more bolls" early in a drought as water (and nitrogen) uptake declines. But if drought continues, these bolls will also shed. When leaves begin to wilt before noon, reactions in the leaf essentially shut down, and foliar applications become ineffective.

Deficiencies also can occur when cotton is heavily fruited, soil moisture is good, and insect control is excellent. Under these conditions, the plant directs most of its resources into making bolls rather than growing new roots and shoots, and nutrient uptake by roots can be less than required to meet peak demands. When deficiencies are detected using plant tissue or petiole analysis, foliar fertilization can improve yields. The real key is to know when deficiencies are present, and the only way to know is to monitor leaf and petiole nutrient levels, also called tissue analysis. **Satisfactory results are highly dependent on knowledge of the specific growth stage (that is, the week of the seedling, early vegetative, bloom, or fruiting period), because critical levels for N and K change dramatically over the reproductive period. In addition, environmental stresses such as unusual wetness, dryness, or cloudy conditions can alter leaf chemistry and complicate interpretation of results.** In these cases, it is best to suspend sampling until more benign environmental conditions return. Cotton leaf and petiole tissue analysis is available from the Agronomic Division of the NCDA&CS at a cost of $7 per sample. Detailed sampling instructions and laboratory data interpretation guidelines are available at www.ncagr.gov/agronomi/pdffiles/11cotton.pdf. Contact your county Extension agent or regional agronomist for assistance if you would like to experiment with this management tool.

Foliar applications of nitrogen or potassium to correct late-season deficiencies are usually made using either urea (46-0-0) or potassium nitrate (13-0-44) as the source. Other materials are available and are being tested, but urea and potassium nitrate have proven to be effective in correcting deficiencies. Generally, the solution is made by mixing 10 pounds of the fertilizer material with 10 to 20 gallons of water for each acre to be treated. Both materials will cause the temperature of the water to drop as they dissolve. Use of warm water or agitation speeds dissolution. By using hot water or extended agitation, solutions as concentrated as 10 to 20 pounds of material in 5 gallons of water can be made. These are primarily used in aerial application. In some areas, premixed solutions are beginning to appear on the market. Both of these materials seem compatible with commonly used insecticides. Check the pesticide label for warnings or instructions on mixing with fertilizers because mixing order may be important. Applications during the first five weeks of bloom are most effective in correcting nutrient deficiencies.

MONITORING PLANT NUTRITIONAL STATUS

Leaf or tissue analysis provides a "snapshot" in time of the nutrients (N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, and B) that have accumulated in the uppermost mature leaves. Tissue analysis is a tool that indicates whether nutrient levels are adequate for the crop to mature with optimum yields. It evaluates nutrient shortages or excesses and helps determine appropriate corrective action. For example, nutrients that are mobile in the soil such as nitrogen (N) and sulfur (S) can easily move out of the root zone by leaching rain; deficiencies due to such loss can be detected with tissue analysis.

When blooms first appear on cotton, the plant has accumulated only about half of its total nutrient uptake (Figure 7-2). At this stage, the root system is still active and the plant continues to accumulate nutrients and to add both vegetative and fruiting sites for several more weeks. From mid bloom through maturity, root expansion as well as nutrient uptake slows even though the crop requires 10 or more weeks to fully mature. At the later growth stages, leaf analysis is less effective in predicting nutrient needs of the crop. Because of this tendency, cotton leaf analysis as a tool to assess nutrient requirements for the current crop is best done during the prebloom or early bloom period.

To monitor fertilizer uptake in an actively growing cotton plant, the most recently mature leaf is the leaf to sample. This leaf blade is four to five nodes down from the terminal leaf (bud) and is generally 10 to 16 days old. About 20 leaves including petioles (stems) are suggested for each sample; ideally the petiole should be removed from the leaf at the time of sampling. The leaf analysis provides information about what occurred a few weeks earlier in regards to plant uptake and storage of nutrients. Although this information can be helpful, petiole analysis has proven to be a reliable indicator of available soil nutrients during the bloom period, especially for nitrate-nitrogen (nitrate). The petiole (leaf stem) has very little storage capacity for nutrients, because its primary function is to channel nutrients to and from the leaf blade. Thus, the nutrient content in the petiole of the uppermost mature leaf is an excellent means to monitor current soil availability. It is a much more sensitive indicator of N availability than leaf analysis. As shown in Figure 7-3, nitrate concentration decreases following bloom. A leaf sampling program should begin prebloom to establish a baseline nutritional status. Then, by comparing petiole nitrate

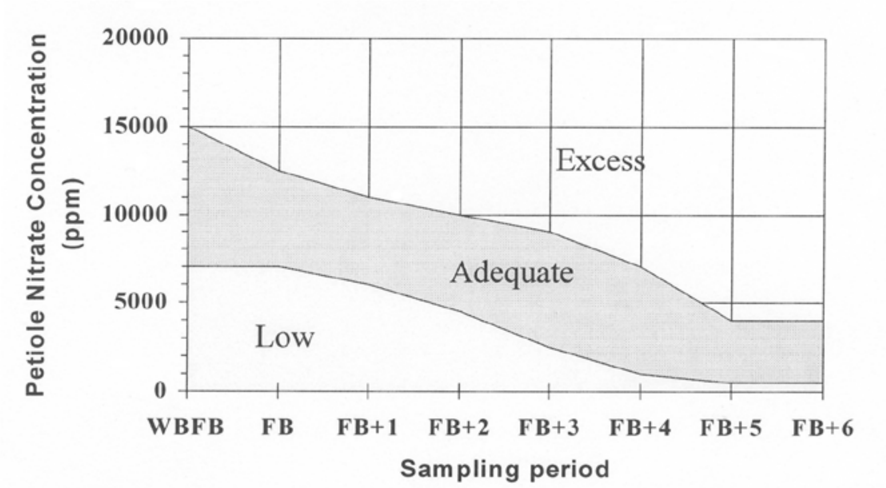

Figure 7-3. Ratings for petiole nitrate concentrations during the bloom period.
(WB = Week Before; FB = First Bloom; number after FB indicates weeks after first bloom.)

levels each week of bloom with final yields in test plots, desired ranges for optimum yields, as established for North Carolina conditions and cultivars, can be used to track nutrition and make nitrogen adjustments. Fields with "low" petiole nitrate will have a high likelihood of responding to additional nitrogen, either applied to the soil if early during the bloom period or as a foliar application if later in the season.

Unfortunately, anything that affects nutrient uptake by the root system, such as drought or excess soil moisture, also strongly affects petiole nutrient levels. **Thus, petiole-monitoring programs are most effective when soil moisture is good to adequate.**

STARTER FERTILIZERS

In a high-management situation, starter fertilizers can enhance early season growth, promote earlier fruiting, and increase yields. Enhanced growth frequently allows more timely and effective weed control. The extent of these effects varies with soil and climatic conditions, and effects may not be seen every year. Responses are usually greatest on early planted cotton in cool, wet soils with low phosphorus levels, especially in reduced tillage systems, but are not limited to these conditions. Over a period of several years, replicated trials with soils testing high in phosphorus have shown an average increase in cotton lint yield of 60 pounds per acre. On soils testing "very high" in phosphorus (P-index greater than 100), there has been no advantage of including additional phosphorus in the starter band (i.e., highest yields occurred with only nitrogen in the starter). The most consistent responses have occurred when the starter is placed in a narrow band 2 inches below and 2 inches to the side of the seed. Other techniques, such as surface bands 3 to 4 inches wide applied over the row, have been successful but are much less consistent. Tests with nitrogen or nitrogen-plus-phosphorus solutions mixed with the preemergence herbicides have been the least successful. This finding could be expected because the fertilizer is sprayed in a much wider band, and the nutrient concentration in the row is greatly diluted. Starter fertilizer trials throughout the Southeast have shown that responses are possible in some cases with nitrogen only, with one-to-one mixes of nitrogen solutions with 10-34-0 or similar ammonium polyphosphate solutions, and with granular fertilizers such as DAP (diammonium phosphate, 18-46-0). A maximum rate of 100 to 120 pounds of starter fertilizer per acre is suggested to maximize response and minimize the chance of seedling injury. Careful setup is essential. Placement too close to the seed can mean replanting. In-furrow fertilizers are not recommended for cotton!

In summary, trials throughout the Southeast support the use of starters on soils where potential yields are greater than 700 pounds per acre and where other good management practices are followed. Starters will not help much where timely weed control, insect management, and nitrogen fertilization are not practiced, but they can help a well-managed crop perform better.

ANIMAL WASTES AS A NUTRIENT SOURCE FOR COTTON

In many of the important cotton-producing areas of North Carolina, poultry and swine manures are available for use on cropland. Manure is often a cost-effective substitute or supplement to fertilizer-supplied nutrients. Animal wastes should be analyzed prior to use to determine the kind and quantity of nutrients in the waste. The largest quantity of nutrients will be nitrogen, phosphorus, potassium, and sulfur, along with some magnesium, calcium, copper, zinc, manganese, and lime. While the rate of manure applied can be adjusted to supply the requirements of any one of these nutrients, make sure that excess available nitrogen is not supplied. Excess nitrogen is more detrimental to cotton than excesses of the other nutrients. In general, 40 to 80 percent of the total nitrogen will be available for uptake by plants in the first year of application; 100 percent of the P and K is plant available the first year. Recent work in Alabama indicates that essentially 100 percent of the nitrogen in poultry litter is available when incorporated just before planting. Animal wastes should be incorporated as soon as possible after application to decrease volatile losses of nitrogen and to lessen the impact of runoff on nearby water bodies. This situation leads to the major problem with use of animal wastes on cotton: all the manure really needs to be applied before planting. As with any nitrogen source for cotton, it is preferable to side-dress most of the applied nitrogen to avoid problems with excessive vegetative growth and delayed fruiting. One solution is to apply animal wastes at a rate to supply sufficient P preplant, then side-dress with a liquid fertilizer at the appropriate rate to obtain the rest of the N needed by the crop. Ongoing research will evaluate the nitrogen availability and rate of release to cotton from various animal wastes.

For more information on the use of animal wastes as nutrient sources, ask your county Cooperative Extension agent for a copy of the SoilFacts publications AG-439-4, *Swine Manure as a Fertilizer Source*; AG-439-5, *Poultry Manure as a Fertilizer Source*; and AG-439-28, *Dairy Manure as a Fertilizer Source*, or visit www.soil.ncsu.edu/publications/extension.html.

8. SUGGESTIONS FOR GROWTH REGULATOR USE

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Growth regulators are used to control cotton plant height. Mepiquat chloride is the active ingredient in products known commonly as mepiquat and available under different trade names, including Pix and Pennax. Mepiquat pentaborate is the active ingredient in the growth regulator named Pentia. These growth regulators are both anti-gibberellens that control plant height and can increase earliness. Several nonmepiquat growth regulators are sold for use in cotton, but there are no data to support the use of any growth regulators that do not contain some form of mepiquat in North Carolina. Because the activity of mepiquat chloride and mepiquat pentaborate are similar, I will refer to them as mepiquat in this chapter. Stance (a premix of mepiquat chloride and cyclanilide) is a product used at lower rates compared to other mepiquat-containing products, due to its higher concentration of active ingredient plus cyclanilide, which acts as a synergist. Experience with this product suggests that Stance, when used at appropriate application rates, has similar effects on plant growth and development when compared to other mepiquat-containing products.

Mepiquat can be applied as a broadcast spray or as a banded spray. Research at North Carolina State University has shown that mepiquat also can be applied through a canvas wick applicator. The greatest advantage the wick seems to have over spray applications is that it makes it easier to apply mepiquat to tall cotton and avoid application to shorter, stressed cotton within the same field. More detailed information about using a wick can be found online via the National Cotton Council: www.cotton.org/journal/2001-05/1/upload/jcs05-009.pdf and www.cotton.org/journal/2001-05/1/upload/jcs05-015.pdf.

PLANT MODIFICATION

Mepiquat can help cotton growers manage the development and maturity of their crop. Research conducted in North Carolina, as well as in other areas of the Cotton Belt, has demonstrated that mepiquat treatment can hasten maturity, reduce plant height, facilitate insect management, decrease boll rot, and increase yield.

These desirable features are caused by the inhibition of cell elongation in the cotton stems. Mepiquat-treated plants are normally smaller and more compact. Internodes along the stem and fruiting branches are shortened. The total number of fruiting branches also may be reduced slightly. Energy is directed toward retention of bolls lower in the canopy and away from vegetative growth, due to increased light penetration to lower subtending leaves.

Normally, our North Carolina season does not give us enough time to mature the bolls produced on the highest fruiting branches. In mepiquat-treated cotton, those positions are not formed. In untreated cotton, those additional fruiting positions frequently are not harvested in later planted or excessively tall cotton. Growers should keep in mind that final plant height should be tall enough to support a good boll load, and thus high yields, but height should not be excessively tall. The ultimate goal of any growth regulator management strategy is to slow terminal growth when growth is occurring too rapidly, and guide the plant to a point where the developing boll load takes over restraining terminal growth, so that upward growth ceases at an optimal plant height. In North Carolina, final plant height should be loosely defined as 38 to 48 inches tall, depending on boll retention and planting date, or other factors.

SEASON CONSIDERATIONS

In rain-fed cotton production, the presence or absence of timely rainfall largely determines the length of the growing season and the plant's ability to produce and mature bolls.

If we experience timely rainfall, cotton normally produces excellent yields, with or without mepiquat. When excessive rainfall occurs, particularly when soil nitrogen is plentiful, mepiquat treatment is usually an excellent investment.

What happens, however, when drought or another stress occurs that limits square production? If the stress occurs three weeks into bloom and continues for the remainder of the bloom period, then mepiquat-treated cotton frequently will out-yield untreated cotton because the mepiquat-treated cotton sets a greater portion of the crop earlier. If, however, the stress occurs during or immediately following the application of 1 pint per acre of mepiquat (a normal application amount), the situation may be quite different.

If drought continues for the remainder of the season, nothing will help. If the drought breaks after one to two weeks, the mepiquat-treated cotton may have a difficult time resuming growth and boll loading because mepiquat tends to reduce vegetative growth and the associated square production.

Treatment with the plant growth regulator does not guarantee the results mentioned above, particularly increased yield. Yields of mepiquat-treated cotton may be reduced when biological and environmental conditions do not favor excessive vegetative (rank) growth. However, a single application of mepiquat with a rate appropriate for plant size rarely decreases yield. As with any management tool, the decision to use mepiquat should be based on a consideration of its usefulness in a specific situation. Your decision to apply mepiquat in any given year should be made on a field-by-field (or portion-of-a-field) basis. Certain cotton fields may require treatment every year, whereas others will rarely require treatment.

CONDITIONS FAVORING MEPIQUAT USE

Mepiquat use is usually warranted when conditions favor rank growth and delayed maturity. The following list includes some of the conditions favoring mepiquat use:

- Cotton planted after May 15
- Thick stands (more than four plants per foot of row)
- High nitrogen rates
- Excessive rainfall within seven days of treatment
- Fields with a history of rank cotton growth
- Large, indeterminate varieties
- Fields with delayed maturity
- Fields that will be defoliated and harvested first

If more of these conditions are present, a positive response to mepiquat treatment is more likely. Conversely, if the above conditions are not present, mepiquat treatment may not be worthwhile.

APPLICATION STRATEGIES

Several mepiquat application strategies have been developed. Three strategies—early bloom, low-rate multiple, and modified early bloom—are discussed below with guidelines for each. The low-rate multiple approach is not recommended in North Carolina due to poor early season growth. One exception might be the presence of vigorous and late-maturing varieties when early weather conditions favor rapid growth.

I. Early Bloom Strategy

The most commonly used technique is the application of ½ pint to 1 pint of mepiquat at early bloom (defined as five to six white blooms per 25 feet of row) on cotton that is more than 24 inches tall if conditions favor a response to mepiquat. Cotton that is less than 20 inches tall at early bloom does not receive a treatment. The ½-pint to 1-pint rate is also applied if the cotton averages 28 inches tall, even if early bloom has not yet occurred.

Applications may be made after early bloom if cotton growth becomes excessive (following early bloom). Treatment rates range between ½ pint and 1 pint per acre. **Note:** Treatments applied later than seven days after early bloom will have less impact on earliness and less potential to increase yield.

Mepiquat use decisions should be based on the development of the crop, environmental conditions, and time of the season. The following guidelines will assist in making situation-specific decisions for mepiquat use. Remember that mepiquat should not be applied to drought-stressed cotton. Wait until stress is relieved before application. Consult the label for additional precautions.

Situation 1
Plant height is less than 20 inches at early bloom because of stress.
Response
Relieve stress if possible. Avoid mepiquat application right away. Treatment may be required later, but wait and see.

Situation 2
Plant height is 20 to 24 inches tall at early bloom.
Response
If bloom begins before July 10, then crop is on schedule. Wait and see. Mepiquat at 1 pint per acre may be required later, particularly if plant height exceeds 28 inches within one week of early bloom.
If bloom begins after July 10, particularly after July 20, then apply ½ pint of mepiquat per acre to compact the boll-loading period if the crop is not under drought stress.

Situation 3
Plant height is more than 24 inches at early bloom; plant is growing rapidly.
Response
Apply ½ pint of mepiquat per acre to reduce shading and improve boll set. An additional ½ pint to 1 pint of mepiquat per acre (depending on previous treatment rate) may be required if plant height exceeds 28 inches one week after early bloom or 32 inches two weeks after early bloom.

Situation 4
Plant height is approaching 20 to 24 inches before early bloom. Growth is rapid; condition well-watered. Anticipated early bloom height is more than 24 inches.
Response
If prebloom cotton is 16 inches tall, apply ¼ pint per acre. If prebloom height is 20 inches or more before first treatment, apply ½ pint per acre. An additional mepiquat treatment may be necessary if plant height exceeds 24 inches at early bloom, 28 inches one week after early bloom, or 32 inches two weeks after early bloom.

II. Low-Rate Multiple Application Strategy
Recently, an alternate strategy has been developed to reduce the risks associated with an early bloom mepiquat treatment that precedes a drought period. This strategy employs the use of low-rate multiple applications (LRMA) of mepiquat beginning at match-head square (50 percent of plants with one or more squares 1/8 inch to ¼ inch in diameter). The first treatment of 1/8 pint to ¼ pint occurs at match-head square if conditions favor a response to mepiquat. Further treatments are made at 7-day to 14-day intervals when conditions favor a response to mepiquat.

This approach is logical and should enable you to achieve the benefits of mepiquat, particularly if you have irrigation capabilities, while reducing the risks associated with the product (early cutout). Instead of running the risk that drought stress may occur immediately after a larger, early bloom treatment, you should be able to mete out smaller doses that enable you to fine-tune the crop's development. Research in North Carolina, however, has shown this strategy to be the one most likely to reduce yields, as compared to the early bloom or modified early bloom strategies.

Remember that pinhead square occurs when a cotton plant's first flower bud is just visible to the naked eye. Match-head square (squares ⅛ inch to ¼ inch in diameter) occurs about 7 days later. First bloom occurs about 21 days after pinhead square and 14 days after match-head square. Early bloom (five to six white blooms per 25 feet of row) occurs within 5 to 7 days of first bloom.

Table 8-1 provides a point system to help producers select rates for the LRMA approach. Because it is impossible to put all considerations into a usable chart, an experienced producer may be able to make better decisions than the chart would recommend. This point system is much better than a "shot-in-the-dark" guess that an inexperienced producer might have to make. Use the appropriate portion of the table for the stage of growth. Total the points to determine mepiquat rates. For example, using Table 8-1 at first square, if you had excellent moisture, a stalk height history of 50 inches, first square on June 20, and a short variety, you would accumulate 1, 2, 1, and 0 points. This accumulation would total 4 points. The total number of points equals the number of ounces of mepiquat that should be applied. In our example, the producer would apply 4 ounces.

III. Modified Early Bloom Strategy

Many producers have a difficult time treating their entire acreage in a timely manner using the early bloom strategy due to large acreage, lack of equipment, or wet weather. This situation often results in applications made too late to successfully control plant size and influence earliness. These producers may wish to use the modified early bloom approach on at least a portion of their acreage. This approach involves possible treatments 10 to 14 days before early bloom (10 to 14 days after first square), at early bloom, and 10 to 14 days after early bloom. The last application is seldom necessary if this approach is used successfully. Table 8-2 presents guidelines for its use.

Note in the charts that the internode length that triggers mepiquat application is 2.5 inches on the first two potential applications. On irrigated cotton or cotton on extremely productive soils, one may want to be less conservative and use 2 inches or 2.25 inches as the trigger.

Table 8-1. Point System for Determining Mepiquat Rates Using an LRMA Approach

FIRST SQUARE

Points

	-1	0	1	2
Moisture		fair	excellent	
Stalk height history	< 36 in.	36 to 44 in.	44 to 48 in.	> 48 in.
Date of first square		before June 15	after June 15	
Variety		short or medium	tall	

If score is greater than 3, do not apply.
If soil moisture is poor, do not apply.
Do not exceed a total of 4 ounces.

10 TO 14 DAYS AFTER FIRST SQUARE

Points

	-1	0	1	2
Moisture		fair	excellent	
Stalk height history	< 36 in.	36 to 44 in.	44 to 48 in.	> 48 in.
Square retention		>75%	<75%	
Prior Mequipat applied		> 3 oz	0 to 3 oz	
Height-to-node ratio	< 1.4	1.4 to 1.7	> 1.7	

If score is less than 3, do not apply.
If soil moisture is poor, do not apply.

EARLY BLOOM

Points

	-1	0	1	2
Moisture	fair	good	excellent	
Plant height	< 20 in.	20 to 24 in.	> 24 in.	> 48 in.
Fruit retention		> 75%	50 to 75%	< 50%
Prior mepiquat applied	> 8 oz	5 to 8 oz	3 to 5 oz	none
Date of first bloom		before July 10	July 10 to 20	after July 20

If NAWB is less than 7, do not apply.
If score is less than 3, do not apply.
If soil moisture is poor, do not apply.

10 TO 14 DAYS AFTER EARLY BLOOM

Points

	-1	0	1	2	4
Moisture	fair	good	excellent		
NAWB	5 or less	5 to 6	6 to 7	7 to 8	above 8
Fruit retention		> 75%	< 75%		< 30%
Prior mepiquat applied		> 12 oz	8 to 12 oz	0 to 8 oz	
Internode length*	< 1.5 in.	1.5 to 2 oz	> 2 in.		

If NAWB is less than 5.5, do not apply.
If score is less than 3, do not apply.
If soil moisture is poor, do not apply.
*The largest of the internodes below the third and fourth main-stem leaf.

Table 8-2. Determining Mepiquat Rates Using a Modified Early Bloom Approach

10 TO 14 DAYS AFTER FIRST SQUARE

	Plant Height		
	< 17 in.	17 to 20 in.	> 20 in.
Height-to-node ratio >1.85	4 oz	6 oz	8 oz
Internode >2.5 in.*	4 oz	6 oz	8 oz

If soil moisture is poor, do not apply.
*The largest of the internodes below the third and fourth main-stem leaf.

EARLY BLOOM — if Mepiquat has already been applied

	Plant Height			
	<24 in.	24 to 27 in.	27 to 30 in.	>30 in.
Plant height >24 in.	0 oz	6 oz	9 oz	12 oz
Internode >2.5 in.*	6 oz	6 oz	9 oz	12 oz

If soil moisture is poor, do not apply.
If NAWB is <7, do not apply.
*The largest of the internodes below the third and fourth main-stem leaf.

EARLY BLOOM — if Mepiquat has NOT been applied

	Plant Height			
	<24 in.	24 to 27 in.	27 to 30 in.	>30 in.
Plant height >24 in.	0 oz	8 oz	12 oz	16 oz
Internode >2.5 in.*	8 oz	8 oz	12 oz	16 oz

Do not apply if soil moisture is poor.
Do not apply if NAWB <7.
*The largest of the internodes below the third and fourth main-stem leaf.

10 TO 14 DAYS AFTER EARLY BLOOM

Mepiquat applied at early bloom

	>8 oz	0 to 8 oz
Internode <2.5 in.*	0 oz	0 oz
Internode 2.5 to 3.5 in.	8 oz	12 oz
Internode >3.5 in.	12 oz	16 oz

If soil moisture is poor, do not apply.
If NAWB is <5.5, do not apply.
*The largest of the internodes below the third and fourth main-stem leaf.

9. DISEASE MANAGEMENT IN COTTON

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Cotton diseases are caused by microorganisms such as fungi, nematodes, and bacteria that grow on and within plant tissues. They often result in reduced vigor and yields and sometimes death. Seeds and seedlings attacked by these pathogens often die, while older plants may survive but perform poorly. Diseases can also result from an inhospitable environment, such as a field with too much or too little water or fertilizer, or from air pollutants, temperatures unfavorable for plant growth, or chemical injury, such as herbicide injury or carryover. Diseases caused by organisms are contagious (will spread from plant to plant) and usually affect only one plant species, whereas disorders caused by environmental factors (abiotic) produce symptoms on all plants in the affected area but will not spread from plant to plant.

Plants are more prone to attack by pathogens when stressed by an inhospitable environment, insects, or other causes. Thus, contagious diseases are often associated with insect infestations and poor growing conditions. For example, wet, cold soils often lead to fungal rotting of seeds and seedlings; insect injury to bolls increases the probability of fungal boll rots.

This chapter discusses cotton diseases that affect seeds, seedlings, and mature plants. Emphasis is placed on fungi and nematodes, the two most important pathogen groups on cotton. Injury to plants caused by fertilizer, herbicides, or environmental problems is covered in other chapters of this publication.

SEED AND SEEDLING DISEASES

Seedling diseases cause an estimated average annual yield loss of 5 percent and are usually the major disease problems of cotton production in North Carolina. Several soilborne fungi are responsible; however, cultural and environmental factors that delay seed germination and seedling growth make the problem more severe.

Environmental Factors and Seedling Disease Control

Seedling disease occurs more frequently under cool, wet conditions. Environmental factors are very important in influencing the development of seedling diseases (Table 9-1). Other factors, such as planting depth, poor seedbed conditions, compacted soil, nematode or insect infestations, and misapplication of soil-applied herbicides, such as dinitroanalines, may increase the problem. Seedling diseases tend to be more severe in reduced tillage situations and when beds are absent. Planting on beds elevates the seed, allowing for more rapid emergence, especially after heavy rains. Plants are more prone to attack by pathogens when stressed by insects or other causes, and contagious diseases are often associated with insect infestations and poor growing conditions. For example, damage from thrips can delay seedling development and enhance damping-off diseases caused by various fungi.

Table 9-1. Point System for Determining the Need for In-Furrow Fungicides*

Factor	When Does It Matter	Points*
Soil temperature	Less than 65°F	75
5-day forecast	Colder and wetter	50
Seed quality	Cold germination less than 59°F	75
Field history	Severe disease	100
Tillage	Minimum tillage	50
Row preparation	Beds absent	75
Seeding rate	Less than 3 to 4 per ft of row	100
Poorly drained soil	Consistently saturated	50
TOTAL		

If total exceeds 200, consider using an in-furrow fungicide.

**This point system is only a guide as to the probability of cotton seed benefitting from an application of an in-furrow fungicide.*

Fungi Causing Seedling Diseases

Several species of fungi can cause seedling disease, but the primary agents are *Pythium* spp., *Rhizoctonia solani*, *Phoma exigua* (*Ascochyta*), and *Fusarium* spp. These disease-causing organisms can attack the seed before or at germination. Plant-parasitic nematodes will generally enhance the ability of these fungi to cause disease by creating wounds for fungi to enter the plant. In addition, herbicide injury, cool/wet weather, heavy thrips pressure, or some combination of these factors could result in slow seedling growth, which could further increase disease presence or intensity. The fungi also can attack the young seedling before or after emergence. Symptoms include seed decay, necrosis of the new root and/or hypocotyl, decay of the seedling before emergence, and partial or complete girdling of the emerged seedling stems. Seed and seedling disease is characterized by a soft, watery rot. Damaged seedlings that emerge are pale, stunted, slower growing, and sometimes die within a few days. Examination of infected seedlings may reveal dark lesions on the stem and root. Often the taproot is destroyed, and only shallow-growing lateral roots remain to support the plant. The "sore shin" phase of seedling disease is characterized by reddish-brown, sunken lesions at or below ground level. These lesions enlarge, girdle the stem, and cause it to shrivel. Seedling diseases do not usually kill the entire seedling population, but result in uneven, slow-growing stands with skips in the rows. In some years, replanting is necessary. Poor stand establishment causes problems with the management of other pests and may reduce yields.

The most common fungi associated with seedling diseases in North Carolina are *Pythium* spp. and *Rhizoctonia solani*. Often both fungi can be found on the same seedling. The same fungus may cause seed decay, seedling root rot, or both. However, *Pythium* spp. and *Fusarium* spp. usually attack the seed and below-ground parts of young seedlings, while *R. solani* usually causes sore shin. *R. solani* and *P. exigua* may attack seedlings from the time they emerge until they are about 6 inches tall. After this stage, the stem becomes woody, and subsequent infection rarely occurs unless the stem is injured.

Pythium spp. Several species in the genus *Pythium* can cause seedling disease in cotton as well as several other crops. *Pythium* spp. are classified as water molds, producing spores that move actively in soil water. In general, *Pythium* is commonly the culprit if the soil has remained saturated for several days or is poorly drained. Fungicides such as mefenoxam (Ridomil Gold) or etridiazole (ETMT, Terrazol) are usually effective in reducing *Pythium* spp. seedling disease.

Rhizoctonia solani. This fungus typically causes sore shin and is more common on sandy, well-drained soils. Plants injured by sand blasting are particularly susceptible to this pathogen. Fungicides such as PCNB (Terrachlor), iprodione (Rovral), azoxystrobin (Quadris), or pyraclostrobin (Headline) are generally effective against *Rhizoctonia solani*.

Phoma exigua (*Ascochyta gossypii*). This fungus can cause postemergence damping-off. This disease is characterized by premature dying of cotyledons, which turn brown and shrivel. *P. exigua* is often observed when night temperatures fall between 50°F to 60°F and are accompanied by foggy or misty conditions (see also *Plant Pathology Cotton Information Note No. 2*). Fungicide effectiveness against *P. exigua* has not been evaluated.

Fusarium spp. Various species of the fungal genus *Fusarium* are typically found on diseased cotton seedlings. Seed-applied fungicides are generally effective in managing it.

SEEDLING DISEASE MANAGEMENT

A control program for seed and seedling diseases is based on preventive rather than remedial treatments. A combination of fungicides and cultural practices to make conditions more favorable for the young cotton and less favorable for the disease-causing organisms is required for seedling disease management. Poor-quality seed with low germination potential should be avoided. For additional information on seedling diseases, see content.ces.ncsu.edu/cotton-seedling-diseases.

Seed Treatment. All cotton seed offered for sale in North Carolina are treated with fungicides. Systemic fungicides provide temporary protection from certain types of preemergence and postemergence damping-off. Several relatively new products are now available for cotton nematode control. These products often work best on low populations of soil nematodes, and determining the level of nematode pressure in a given field is important for selecting the proper seed treatment. Chemicals available include Avicta Complete Cotton from Syngenta, which also has the insecticide Cruiser for thrips control and additional fungicide treatments on the seed, and Aeris with Poncho/Votivo or Trilex Advanced, which has an option to add Gaucho Grande for thrips control and additional fungicides if desired by the producer. Avicta complete pack has abamectin (a nematicide), and Aeris has thiodicarb (Larvin), which acts as a nematicide. Acceleron is another brand offered by Monsanto that can provide some control of diseases, thrips, and nematodes, depending on the version requested. A plethora of chemistries are also offered through downstream seed-treaters.

In most years, seed treatment fungicides are sufficient for controlling seedling disease, unless the quality of the seed is low or weather conditions are unfavorable for germination.

Reduced Tillage. Despite soil property benefits, the recent trend to low-till or no-till cotton has resulted in an increase in the frequency and severity of seedling diseases. The inoculum of pathogens from previous crops overwinters in crop debris, and reduced tillage preserves the debris adjacent to emerging seedlings whereby pathogens have little distance to infest susceptible tissues. The lack of a raised bed, inadequate seed bed preparation, and additional crop residue associated with reduced tillage all contribute to delays in emergence and stand establishment. The use of an in-furrow fungicide or seed treatment should be considered in reduced tillage situations.

Rotation. Rotating cotton with other nonhost crops helps prevent buildup of some cotton diseases. Continuous cropping to one host crop usually causes an increase in disease. *Rhizoctonia solani*, for example, can grow on dead plant remains and later infect nearby seeds, roots, or stems of susceptible hosts.

Plant Health Promotion. Proper fertilization and liming promote early growth, which gets the seedling to a resistant stage sooner. Early cutting and shredding of stalks aid in the control of seedling disease by reducing the amount of inoculum that carries over from year to year. Also, it is important to prepare a good seed bed to control seedling disease. Raised beds give some control of seedling disease, especially in early planted cotton, by improving soil drainage. Avoid planting when soil temperatures are below 65°F. Below this temperature, germination is slow, and the seed and seedlings are more vulnerable to infection.

FIELD DISEASES

Boll Rot. Boll rot is generally a problem when excessive insect damage or excessively wet conditions exist. Boll rot typically starts with small brown lesions that expand until the entire boll becomes blackened and dry. Chapter 11, “Managing Insects on Cotton,” and chapter 2, “The Cotton Plant,” explain how to reduce insect damage and lower humidity in the canopy (by preventing rank growth) to reduce boll-rot problems.

Fungal Leaf Spots. Several pathogens cause leaf spots on cotton, including Alternaria leaf spot (*Alternaria* spp.), Cercospora leaf spot (*Cercospora* spp.), Ascochyta blight (*Phoma exigua*), Target spot (*Corynespora cassiicola*), and Stemphylium leaf spot (*Stemphylium solani*). Cotton leaves often get small, brown, circular lesions that enlarge to approximately ½-inch. Old lesions sometimes develop gray centers, which may fall out. Differentiating between causal agents of leaf spots is difficult, and often requires the aid of the North Carolina State University Plant Disease and Insect Clinic. Leaf-spot diseases are typically of minor importance, appearing when plants are under nutritional stress or periods of high moisture. Sometimes lesions are not a disease, but rather phytotoxicity symptoms caused by a variety of crop protection chemicals. Leaf spots may be minimized by using the proper amounts of fertilizer and adequate drainage and by reducing rank vine growth, which can promote excessively high humidity in the crop canopy.

Bacterial Blight. Bacterial blight, also known as angular leaf spot, is caused by the bacterium *Xanthomonas compestris* pv. *malvacearum*. Bacterial blight initially appears as angular leaf spots with a red or brown border, and spots may spread along the major leaf veins. Premature defoliation may occur and bolls may become infected, causing a boll rot that results in discolored lint and rotted seed. This disease is promoted by high amounts of rainfall and humidity in conjunction with warm temperatures. There are no corrective measures to reduce disease after a field is infested. Planting high-quality, acid-delinted seed, planting bacterial blight-resistant varieties (where available), proper plant spacing to reduce humidity in the canopy, applications of plant growth regulators to prevent rank growth, and destruction of crop debris after harvest will reduce incidence of bacterial blight under conducive environmental conditions for disease development.

Cotton Stem Canker. Cotton stem canker is caused by the fungus *Phoma exigua* (often referred to as *Ascochyt*a). This fungus typically causes a leaf spot in North Carolina during wet years, but cool, weather wet weather is required for the development of this disease. Management measures for this disease are limited. Rotation has little impact on this disease due to the wide host-range, including other field crops and weed species present in North Carolina. Fungicides currently labeled for foliar application on cotton in the Southeast may not provide adequate control of this disease. Canker-resistant cotton varieties are not likely to be available. For additional information on cotton stem canker, see www.ces.ncsu.edu/depts/pp/notes/Cotton/cdin2/cdin2.htm.

NEMATODES

Nematodes are microscopic worms that feed on or in plant roots, robbing them of nutrients and causing injury. Nematodes occur in damaging levels in approximately 5 percent of the cotton fields of the state (Table 9-2). But problems are more common and severe in the southeastern counties, where as many as 50 percent of the fields may be infested with damaging levels of nematodes. This high level of infestation is probably due to intensive cotton production (short or no rotation) and the lack of resistant varieties. Table 9-2 lists the plant-parasitic nematodes that damage cotton and the current economic thresholds.

Nematode problems are most common in coarse-textured, sandy soils, although the reniform nematode is often a problem on heavier land. Damage caused by nematodes limits water and nutrient uptake and makes the root system more susceptible to other diseases. Symptoms can include increased seedling disease (root-knot and reniform nematodes), stunting, lower yield, poor stands, loss of green color, root galling (root-knot), stunted roots (sting and Columbia lance nematodes), and various nutrient deficiency symptoms. In some cases, there can be yield reduction without visible symptoms aboveground. For example, reniform nematodes may cause 5 to 15 percent reduction in cotton lint yield in apparently healthy cotton fields. Yield losses caused by nematodes often result from abortion or dropping of bolls because of nematode-induced nutrient or water stress.

Table 9-2. Probability of Nematode Damage to Cotton

	Numbers of Nematodes per Pint of Soil (fall count)		
Nematode	**Slight**	**Moderate**	**High**
Root-knot nematode	0-749	750-1,499	1,500+
Stubby-root nematode	0-299	300-499	500+
Sting nematode	0*	0*	10+
Lance nematodes:			
common	0-999	1,000+	
Columbia	0-99	100-499	500+
Reniform nematode	0-999	1,000-1,999	2,000+

** Any detectable number can pose a serious problem.*

Although the northeastern portion of the state is thought to have no significant nematode problems due to extensive rotations of cotton with peanuts, soil samples with damaging levels of root-knot nematodes after cotton have increased significantly in all areas of North Carolina in recent years. Growers should monitor nematodes through soil sampling when cotton is grown without rotation or in rotation with other crops susceptible to the southern root-knot nematode, such as most vegetable crops, some soybean varieties, tobacco, corn, or cucumbers. The southern portion of the state has historically experienced nematode damage, and other areas can expect similar problems if cotton production continues to intensify.

Information from North Carolina State University surveys and from the NCDA&CS Nematode Advisory Service provides a fairly accurate assessment of nematode infestations across the state. Root-knot nematodes were found in all counties, and most of the fields where nematodes were found experienced nematode damage.

Sampling for Nematodes

The types and numbers of nematodes in fields can be determined through collecting soil samples. Soil samples collected in the fall (September through November), when nematode numbers are highest, provide the best information, although samples can be collected anytime. The general procedure for collecting a soil sample for a nematode assay is outlined in the pamphlet *A Nematode Diagnostic and Advisory Service for North Carolina*, available from your county Extension agent or online at www.ncagr.gov/agronomi/pdffiles/samnemas.pdf. Briefly, it suggests that a soil sample represent no more than four to five acres that have been farmed uniformly, and that at least 20 probes of soil be obtained from the top 6 to 8 inches of soil using a soil probe approximately 1 inch in diameter. Thoroughly mix the collected soil in a bucket, place a 1-pint sample in a plastic bag, and take it to your county Extension agent. Include $3 for processing. Samples will be forwarded to the NCDA&CS Nematode Advisory Service, where nematodes are separated from the soil and counted. Numbers reported to you and your county Extension agent represent the number of nematodes per pint (500 cc) of soil.

Crop rotation is used to aid the Nematode Advisory Service in interpreting the importance of nematodes found. For example, there are four common species of root-knot nematodes found in North Carolina, but only one species (southern root-knot, *Meloidogyne incognita*) is a parasite on cotton. Determining what nematodes are present in your soil will aid in developing a crop rotation strategy for each field.

Nematode Control Strategies

Cotton nematode control is accomplished through crop rotation, resistance, and nematicides. Planting in conditions that promote rapid seedling growth is ideal. Rapid development of an adequate root system while avoiding factors that would hinder root growth could help improve stand establishment and yields, especially when low nematode numbers are present. This planting strategy is often insufficient when high nematode numbers are present. Other factors that hinder rapid root development may exacerbate the effects of nematodes, such as low pH, herbicide injury, cool and wet conditions, and heavy pressure from thrips. Some varieties have shown extreme susceptibility to Columbia lance nematode and should be avoided in heavily infested fields. Historically, full-season cotton varieties generally perform better than short-season ones when Columbia lance nematode is present. Several modern varieties are touted by seed companies to convey tolerance to root-knot nematodes (Table 9-5). Ideally, the performance of tolerant varieties should be good whether nematodes are present or not.

Nematode control is best accomplished by preventing the buildup of harmful numbers of these parasites through rotation to crops that do not support nematode reproduction (Table 9-3). Subsoiling can help reduce losses due to Columbia lance and other nematodes in areas where a hardpan is common. Destroying cotton roots after harvest will help reduce nematode survival in general because cotton is a perennial plant and some reproduction may occur after cotton harvest if soil temperatures remain warm. Some weeds also serve as hosts for nematodes and should be controlled in cotton and rotational crops.

Cover crops like rye or wheat may aid in suppression of reniform and Columbia lance nematodes. Rye and wheat, however, are fair hosts for root-knot, Columbia lance, sting, and stubby-root nematodes. Cover crops should be planted as late in the fall as possible and either killed or tilled under in the spring before soil temperatures increase above 55°F to prevent nematode reproduction.

Table 9-3. Suitability of Various Crops for Reducing Cotton Nematode

	Rotational Crop	
Nematode	**Nonhost**	**Host**
Southern root-knot	Sorghum Grasses Grain Alfalfa Peanuts Soybeans (resistant)	Cotton Corn Soybeans (susceptible)
Lesion	Grain Corn Peanuts	Cotton Soybeans
Sting	Watermelons Clover[2] Alfalfa Grain Tobacco	Cotton Corn Soybeans Peanuts
Columbia lance	Grasses Peanuts Tobacco Small Grain Milo	Sorghum Soybeans Cotton Cantaloupes Corn
Reniform	Grasses Corn Peanuts Small Grain Sorghum Mustard Turnips Peppers Soybeans (resistant	Soybeans (susceptible) Cotton Cantaloupes Sweetpotatoes Tobacco Cucumbers

[1] *Other root knot species may be found within a field if a control failure is observed with rotation to these crops. Contact your county Extension agent if a control failure is observed.*

[2] *Except for white clover*

Velum Total, which became commercially available in 2015, is a liquid product applied in-furrow at planting and is touted to control several nematode species. To date, there are little data with regard to Velum Total's performance in nematode infested fields, and results across the Southeast vary. However, preliminary research suggests that under low to moderate pressure, Velum Total has resulted in positive yield responses occasionally but inconsistently, and the number of nematodes may not be drastically affected depending on when samples are taken. Other researchers report a reduction in root galling with little or no yield response. Results from three replicated on-farm trials during 2015 to 2016 showed positive yield responses associated with Velum Total in historically nematode-problematic fields. On-farm research continued in 2017, but results are not yet available. This product is mentioned in this chapter simply as a commercial option, and recommendations for its use will be further developed as we gain more experience with Velum Total in replicated trials.

Table 9-4. Nematicides for Control of Cotton Nematodes[1]

Nematicide	Amount/acre	Precautions/Remarks
Aeris	—	Imidacloprid plus thiodicarb seed treatment.
AVICTA Complete Pack	—	Abamectin plus thiomethoxam seed treatment.
Poncho Votivo	—	Clothianidin plus *Bacillus firmus* I-1582 seed treatment
Acceleron NemaStrike SP	—	Tioxazafen seed treatment.
Aldicarb (AgLogic) 15G	5 to 7 lb	Apply in-furrow and immediately cover with soil by mechanical means.
1,3-dichloropropene (Telone II) + Aldicarb (AgLogic)15G[2]	1.5 to 6 gal + 3.50 lb	Inject Telone 1 to 2 weeks before planting 8 to 12 inches deep. Apply AgLogic in-furrow at planting.
Aldicarb (AgLogic) 15G + Vydate C-LV[3]	5 to 7 lb + 8.5 to 17 fl oz	Apply AgLogic in-furrow at planting. Broadcast Vydate at 2nd to 5th true leaf stage.
Metam-sodium (Vapam) + Aldicarb (AgLogic) 15G	3 to 12 gal + 3.5 lb	Inject Vapam 2 to 3 weeks before planting 8 to 12 inches deep. Apply AgLogic in-furrow at planting.
Velum Total	14 to 18 oz	Liquid applied in-furrow. Very limited data available, but this product is a commercial option.

[1] See label for proper PPE, rates, and restrictions associated with each chemical. Chemical treatments listed are not exhaustive, and several seed treatment and in-furrow chemical options are available from different chemical companies.
[2] See restrictions for soil type and water proximity on label
[3] Vydate for root-knot and reniform nematode only.

Table 9-5. Variety Resistances for Common Diseases of Cotton

Variety	Root Knot Nematode	Fusarium Wilt	Verticillium Wilt	Bacterial Blight
ST 5020GLTP	MR [1]	MR	MR	R
ST 49494GLT	MR	MR	MR	S
ST 5115GLT	MR	MR	MR	R
ST 4946GLB2	R	R	MR	S
ST 6448GLB2	MR	MR	MR	R
NG 4601 B2XF	MR	MR	MR	S
NG 3406 B2XF	R	R	MR	S
NG 3522 B2XF	N/A	N/A	MR	S
NG 1511 B2RF	R	R	MR	S
AM UA48	R	R	R	R
DP 1725 B2XF	N/A	R	S	S
DP 1747NR B2XF	R	MR	N/A	S
DP 1646 B2XF	N/A	MR	MR	MR
DP 1558NR B2RF	R	S	R	S
DP 1522 B2XF	N/A	MR	MR	S
DP 1252 B2RF	N/A	S	MR	S
DP 1050 B2RF	N/A	MR	MR	S
3109 B2XF	N/A	N/A	MR	N/A
3445 B2XF	N/A	N/A	HT	HT
3544 B2XF	N/A	N/A	HT	HT
3635 B2XF	N/A	HT	N/A	N/A
3226 B2XF	N/A	N/A	LT	S
PHY 220 W3FE	N/A	N/A	HT	N/A
PHY 427 WRF	R	N/A	N/A	N/A
PHY 490 W3FE	N/A	N/A	N/A	R
PHY 575 WRF	N/A	N/A	N/A	R
PHY 805 RF	N/A	MT	N/A	N/A
PHY 811 RF	N/A	HT	N/A	N/A
PHY 841 RF	N/A	HT	N/A	N/A

[1] Resistance level of a variety to a given disease denoted by R = resistant, MR = moderately resistant, S = susceptible, HT = high tolerance, MT = moderate tolerance, LT = low tolerance, or N/A = resistance information not available.

10. WEED MANAGEMENT IN COTTON

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Effective weed management is one of many critical components of successful cotton production. Cotton requires better weed control than either corn or soybeans. Because cotton does not compete well with weeds, especially early in the season, a given number of weeds will reduce cotton yield more than corn or soybean yield. Weeds also may interfere with cotton harvest and reduce lint quality because of trash or possibly stain.

CROP ROTATION

Crop rotation aids in the management of nematodes and diseases, and it can be a significant component of weed management. Crop rotation allows the use of different herbicides on the same field in different years. By effectively controlling weeds in rotational crops, one can reduce or prevent the buildup of problem weeds and help keep the overall weed population at lower levels. **Crop rotation and properly planned herbicide rotation are also critical components of a herbicide resistance management strategy.** See the section on *Herbicide Resistance Management.*

When selecting a herbicide program for crops that will precede cotton, consider rotational restrictions for the various products. This information can be found on herbicide labels. Many of the commonly used herbicides for corn, peanuts, sorghum, soybeans, and tobacco do not carry over to cotton. However, labels for products listed below contain significant rotational restrictions for cotton. Similarly, cotton herbicides, such as diuron, fluometuron, prometryn, prometryn + trifloxysulfuron, pyrithiobac, and trifloxysulfuron have rotational restrictions for other crops. See Table 10-1 for brand names.

Active ingredient	Products containing active ingredient
chlorsulfuron	Finesse Cereal & Fallow, Finesse Grass & Broadleaf
diclosulam[1]	Strongarm[1]
imazaquin	Scepter
imazapic	Cadre, Impose
imazethapyr	Authority Assist, Extreme, Latir, Lightning, Matador, Optill, Praxis, Pursuit, Tackle, Thunder, Thunder Master, Zidua Pro
sulfentrazone	Authority Assist, Authority Elite, Authority First, Authority Maxx, Authority MTZ, Authority XL, Blanket, Broadaxe, Sonic, Spartan, Spartan Charge, Spartan Elite, Sulfentrazone, Zone

[1] Rotational restrictions apply only to Camden, Currituck, Pasquotank, and Perquimans counties.

PLANNING A HERBICIDE PROGRAM

Before selecting one or more herbicides, you should know what weeds are present or expected to appear, the soil characteristics (such as texture and organic matter content), the capabilities and limitations of the various herbicides, and how best to apply them.

Weed Mapping

The first step in a weed management program is to identify the problem. This step is best accomplished by weed mapping. Survey fields each fall and record species present, location, and general population levels. Species present in the fall will likely be the predominant problems during the following year. You can better plan a herbicide program if you know ahead of time what species to expect. In addition, by referring to weed maps over a period of two or three years, you can detect shifts in the weed populations and adjust the herbicide program in response to those shifts.

In-Season Monitoring

During the first 8 weeks after planting, check fields at least weekly to determine the need for postemergence herbicides. After 8 weeks, check fields periodically to evaluate the success of the weed management program and to determine the need for preharvest control measures. If weeds are controlled for the first 8 to 10 weeks, later emerging weeds will seldom become problems.

Proper weed identification is necessary because different weed species respond differently to various herbicides. Contact your local Extension center for aid in weed identification.

Application rates for some soil-applied herbicides depend on soil texture and organic matter content. Failure to adjust application rates for these soil characteristics may result in poor weed control or crop injury.

Before using any herbicide, learn the capabilities and limitations of the various products labeled for cotton, how best to apply them, what weeds they will and will not control, and any special considerations, such as rotational restrictions.

BURNDOWN IN NO-TILL OR STRIP-TILL COTTON

Cover crops (or heavy stands of winter weeds) should be killed at least two to three weeks before planting. This practice will avoid soil moisture depletion by the cover crop or weeds, allow the soil to warm quicker, reduce cutworm problems, and allow time to apply additional burndown herbicide, if needed, to kill streaks that may have been missed during the initial application. Heavy residue from a cover crop will help suppress weeds, but growers should consider their equipment capabilities for strip-tilling and planting into residue in deciding when to terminate a cover crop. Recommended burndown herbicides and application rates for small grain cover crops are outlined in Table 10-2.

If no-tilling or strip-tilling into natural cover (i.e., winter weeds), the need for an early burndown treatment will depend on the weed species present and weed size. An early burndown is normally advantageous, especially if ryegrass, cutleaf eveningprimrose, wild mustard, wild radish, curly dock, or glyphosate-resistant horseweed is present. For recommendations on the burndown of natural cover, see Table 10-3.

Growers are strongly encouraged to incorporate 2,4-D or dicamba into their burndown programs. Several species, including cutleaf eveningprimrose, common eveningprimrose, curly dock, field pansy, vetch, and larger wild radish, are not adequately controlled by glyphosate alone. In addition, glyphosate-resistant horseweed is now very common across North Carolina. See the discussion on glyphosate-resistant horseweed in the section *Herbicide Resistance Management*. There are waiting intervals between application of 2,4-D or dicamba and cotton planting; see details in Table 10-2. Ideally, 2,4-D or dicamba will be applied in March. Suggested rates of 2,4-D vary by species. For cutleaf eveningprimrose, 6 to 8 fluid ounces of a typical 3.8 pound per gallon 2,4-D formulation are adequate. Use 1 pint for other weeds, and 2 pints for glyphosate-resistant horseweed. A residual herbicide, such as flumioxazin (see Table 10-1 for brand names), is also recommended in the mixture to control later-emerging glyphosate-resistant horseweed and to provide residual control of glyphosate-resistant Palmer amaranth. Management programs for these weeds are discussed in the section *Herbicide Resistance Management*. In addition to the burndown herbicide applied a few weeks ahead of planting, one normally needs to apply glyphosate or paraquat at planting to kill any weeds emerging after the earlier burndown application. In most cases, paraquat is the preferred burndown herbicide at planting.

A two-step burndown program may be a consideration in fields with a history of heavy winter weed infestations and where one will be planting into the previous crop's stubble in the absence of a cover group. Thifensulfuron plus rimsulfuron premix (see Table 10-1 for brand names) plus glyphosate can be applied in late fall or early winter. Thifensulfuron plus rimsulfuron added to glyphosate will improve control of henbit and wild radish as compared to glyphosate alone. If horseweed or cutleaf eveningprimrose is emerged, also include 2,4-D or dicamba. Thifensulfuron plus rimsulfuron will provide residual control of later-emerging winter weeds, including horseweed. This late fall or early winter application will then be followed by a second burndown containing flumioxazin about three weeks ahead of planting. Flumioxazin, in this case, is recommended to aid in control of Palmer amaranth. Flumioxazin will give some residual control of Palmer amaranth after planting in case rainfall needed to activate preemergence herbicides is not received. If the thifensulfuron plus rimsulfuron controls weeds as expected, 2,4-D or dicamba may not be needed in this second burndown application.

WEED MANAGEMENT IN ROUNDUP READY FLEX COTTON

Comparing Glyphosate Brands

Several brand names and formulations of glyphosate are available. Products vary in their concentration of active ingredient. Labels for some brands direct the user to add nonionic surfactant. Other brands are "loaded formulations," meaning additional surfactant is not necessary in most cases. Read the label of the brand you use to determine the need for surfactant.

The best way to compare various glyphosate products and application rates is on the basis of acid equivalence (a.e.). See Table 10-9 for assistance in determining the rate of formulated product that gives the desired rate in pounds a.e.

Timing of Application

Brands of glyphosate with specific labeling for Roundup Ready Flex cotton may be applied overtop or directed any time from cotton emergence until seven days prior to harvest. The maximum rate for any single application between crop emergence and the 60 percent open boll stage is 1.125 pounds a.e. (see Table 10-9 for assistance in determining rates of formulated product). A total of 4.5 pounds a.e. can be applied during this time frame. Hence, depending upon application rate, four to six applications can be made overtop or directed. An additional 1.55 pounds a.e. can be applied from the 60-percent-open-boll stage until seven days prior to harvest. Although labeling allows numerous applications of glyphosate, growers should not overly rely on glyphosate. See the section on *Herbicide Resistance Management*.

Need for Soil-Applied Herbicides

Weed resistance to glyphosate is a serious problem (see section on *Herbicide Resistance Management*). A key component of a resistance management strategy is to use multiple herbicide mechanisms of action. Use of preplant and/or preemergence residual herbicides in Roundup Ready Flex cotton is strongly encouraged. These herbicides will not only aid in resistance management but also make timing of the first glyphosate application much less critical.

Should replanting be necessary where preemergence herbicides have been used, it is best to run the planter back in the original drill without any soil preparation if soil conditions permit. In this case, do not apply any additional residual herbicides. If weeds have emerged, glyphosate or paraquat can be applied for burndown. Paraquat will also control emerged cotton from the first planting.

If reworking the seedbed is necessary, use shallow tillage such as light disking. Do not apply additional preplant-incorporated herbicide. If the original preemergence herbicide was broadcast, do not apply any more. If the preemergence herbicide was originally banded, a second preemergence banded application at the minimum rate for the soil type would be in order.

Do not rebed without first disking. Rebedding without disking can lead to severe crop injury.

Tank Mixes with Glyphosate Applied Overtop

Pyrithiobac (Pyrimax, Pysonex, or Staple LX) can be mixed with glyphosate and applied overtop of Roundup Ready Flex cotton from the cotyledonary stage until 60 days prior to harvest. Pyrithiobac rates in a glyphosate tank mix range from 1.3 to 3.8 fluid ounces.

A mixture of glyphosate plus pyrithiobac will improve control of hemp sesbania, morningglory (except tall morningglory), spreading dayflower, and glyphosate-resistant Palmer amaranth (assuming it is not also ALS-resistant) as compared with glyphosate alone. Pyrithiobac also may give residual control of susceptible weeds, such as pigweed species, spurred anoda, and velvetleaf. Palmer amaranth resistant to pyrithiobac and other ALS inhibitors is very common in North Carolina.

Compared with glyphosate alone, a mixture of glyphosate plus pyrithiobac may injure cotton. Applied overtop, pyrithiobac often causes temporary yellowing of the cotton bud. Research has demonstrated that cotton recovers quickly, and there is seldom an adverse effect on yield or maturity. On occasion, however, pyrithiobac applied overtop can cause moderate to severe injury. The potential for significant injury from pyrithiobac appears to be greater when the herbicide is applied during or shortly before a period of cool temperatures. In addition to cool temperatures, other stresses such as wet weather, seedling disease, or thrips damage may worsen injury. Slower recovery from pyrithiobac injury has particularly been noted on cotton infested with thrips.

Trifloxysulfuron (Envoke) can be mixed with certain brands of glyphosate and applied overtop of Roundup Ready Flex cotton from the five-to-12-leaf stage. The mixture may cause some yellowing in the cotton terminal and shortening of internodes. Less response is typically observed on larger cotton. Compared to the glyphosate products alone, the mixture will give greater control of nutsedge, morningglory, and smartweed.

S-metolachlor (Brawl, Brawl II, Dual Magnum, Dual II Magnum, EverPreX, Medal, Medal II) can be applied overtop of cotton that is at least 3 inches tall until 100 days prior to harvest. Crop injury from a mixture of glyphosate plus S-metolachlor overtop is typically minor, with only necrotic speckling noted on leaves exposed to the spray. This injury is temporary; no speckling on later-emerging leaves, no stunting, and no adverse effect on yield or maturity have been noted. The exception has been when additional adjuvants or insecticides are included in the mixture. In some cases, severe injury has been observed when adjuvants or insecticides were included in the mixture. Injury will also be greater if S-metolachlor is applied when dew is on the cotton or when the weather is extremely hot and humid.

Mixing S-metolachlor with glyphosate will have little to no effect on control of emerged weeds by glyphosate. However, if timely rainfall for activation is received, S-metolachlor in the mixture can provide residual control of most annual grasses (only suppression of Texas panicum), pigweed species (including Palmer amaranth), and doveweed, and suppression of yellow nutsedge and spreading dayflower. S-metolachlor mixed with glyphosate may also broaden the window of application for directed herbicides on pigweed species, including Palmer amaranth.

Both metolachlor and S-metolachlor are available. Growers should be aware that metolachlor is less effective than S-metolachlor. Metolachlor is a mixture of four stereoisomers. Two of the isomers (referred to as S-metolachlor) are herbicidally active, whereas the other two isomers (referred to as R-metolachlor) have little herbicidal activity. Check the ingredient statement on the label before buying. Products whose labels designate S-metolachlor contain primarily the active isomers. Labels for products containing metolachlor specify the same rate of formulated product per acre as those containing S-metolachlor, hence growers are getting less of the active form of the herbicide when using metolachlor products. One would have to increase the rate of a metolachlor product by 50 percent to get the same activity as a product containing S-metolachlor.

Labels advise growers to not mix S-metolachlor or metolachlor products with pyrithiobac although research has generally shown this not to be a problem.

A prepackaged mixture of the potassium salt of glyphosate plus S-metolachlor (Sequence) is available. Applied at 2.5 pints per acre, this premix is equivalent to 0.7 pound a.e. of glyphosate plus 1 pint of S-metolachlor.

Acetochlor (Warrant) can be used in a manner similar to S-metolachlor. Acetochlor plus glyphosate can be applied after cotton is completely emerged but before first bloom. Weed control and crop tolerance is similar to that with S-metolachlor. Acetochlor does not control emerged weeds. Best results will be obtained, especially on Palmer amaranth, if acetochlor plus glyphosate is applied to one-to-two-leaf cotton before Palmer amaranth emerges. A second application can be made, or one can apply acetochlor in the first application and S-metolachlor in the second application.

Dimethenamid (Outlook) can be applied overtop in a mixture with glyphosate. Dimethenamid can be applied overtop from the first-true-leaf stage until midbloom. Make only one application per year. Similar to S-metolachlor and acetochlor, dimethenamid has no activity on emerged weeds but it will provide residual control of pigweed species, including Palmer amaranth, and annual grasses. Research to date has shown that crop tolerance is similar to that with S-metolachlor or acetochlor.

Clethodim, fluazifop, quizaqlofop, and sethoxydim (see Table 10-1 for brands) can be mixed with glyphosate applied to Roundup Ready Flex cotton to control volunteer Roundup Ready corn.

Tank Mixes with Glyphosate Directed

In almost every case where glyphosate is being directed, it is advisable to tank-mix another herbicide with the glyphosate to improve control of certain species or to provide some residual control. Tank mixes are also recommended as part of a resistance management program (see section on *Herbicide Resistance Management*). Potential tank-mix partners with glyphosate applied postemergence-directed include Aim, diuron, Dual Magnum, Envoke, Fierce, flumioxazin, prometryn, pyrithiobac, Suprend, Warrant, and Zidua. See Table 10-2.

Carfentrazone (Aim) is very effective on morningglory, and carfentrazone mixed with glyphosate will improve control of larger morningglory compared to glyphosate alone. Cotton should be at least 16 inches tall, and the spray must be directed precisely to the woody portion of the stem. Spray contact with green stem tissue will cause injury. This combination does not provide residual control.

Diuron or prometryn (see Table 10-1 for brand names) mixed with glyphosate will improve control of larger morningglory compared to glyphosate alone. Products containing diuron applied at 1.5 pints or products containing prometryn applied at 2 pints will provide some residual control of small-seeded broadleaf weeds, such as pigweed, if an activating rainfall is received. Diuron is generally more effective on pigweed, including Palmer amaranth, than prometryn. Cotton should be at least 12 inches tall before directing diuron or prometryn at these rates. Occasionally, mixing diuron or prometryn with glyphosate will reduce grass control by glyphosate or at least delay death of the grasses. This event is most likely to occur under dry growing conditions when grasses are large. Do not reduce the glyphosate rate when tank-mixing.

Prometryn plus trifloxysulfuron (Suprend) mixed with glyphosate will improve control of larger morningglory and nutsedge. It also will provide residual control of susceptible broadleaf weeds. Cotton should be at least 6 inches tall when directing prometryn plus trifloxysulfuron.

Flumioxazin (Outflank, Panther, Rowel, Valor SX, Warfox) mixed with glyphosate will improve control of doveweed, Florida pusley, and larger morningglory, compared to glyphosate alone, and will provide good residual control of Palmer amaranth. Cotton needs to be 16 inches tall, and the spray should be allowed to contact only the bottom 1 to 2 inches of the cotton stem.

Flumioxazin plus pyroxasulfone (Fierce) can be used in the same manner as flumioxazin, discussed above. It provides excellent residual control of grasses and many broadleaf weeds, including Palmer amaranth.

Pyrithiobac (Pyrimax, Pysonex, or Staple LX) mixed with glyphosate will improve control of hemp sesbania, morningglory (except tall morningglory), spreading dayflower, and glyphosate-resistant Palmer amaranth compared to glyphosate alone. Pyrithiobac can also provide residual control of susceptible species such as prickly sida, pigweed species, spurge, velvetleaf, and spurred anoda. Palmer amaranth resistant to pyrithiobac and other ALS inhibitors is very common in North Carolina.

Trifloxysulfuron (Envoke) mixed with glyphosate will improve control of nutsedge and larger morningglory compared to glyphosate alone. Cotton should be at least 6 inches tall. Trifloxysulfuron has residual activity on susceptible broadleaf weeds, including Palmer amaranth. Palmer amaranth resistant to trifloxysulfuron and other ALS inhibitors is common in North Carolina.

Acetochlor (Warrant), **pyroxasulfone** (Zidua), or **S-metolachlor** (Brawl, Brawl II, Dual Magnum, Dual II Magnum, Medal, Medal II) mixed with glyphosate will not improve postemergence weed control compared to glyphosate alone. However, if these herbicides are activated by rainfall, they will provide residual control of annual grasses and small-seeded broadleaf species, including Palmer amaranth. Acetochlor can be directed anytime up to first bloom of cotton. Pyroxasulfone can be directed from the five-leaf stage to first bloom. S-metolachlor can be directed to cotton that is at least 3 inches tall through layby. Do not apply pyroxasulfone over top.

Glyphosate versus Other Directed Herbicides

On glyphosate-tolerant cotton, one has the option of directing either glyphosate or a traditional herbicide combination. Better broadleaf weed control is sometimes obtained when traditional directed herbicides are used. If, however, grasses are a predominant problem, and they are larger than 1 to 1.5 inches, glyphosate may be the more effective option. Other herbicides should be mixed with directed glyphosate to enhance broadleaf control; see discussion under *Tank Mixes with Glyphosate Directed*. This mix will also help in resistance management. Alternatives to glyphosate for directed application are presented in Table 10-2 under the section on *Postemergence-Directed Herbicides – Any Variety*.

Difficult-to-Control Weeds in Roundup Ready Systems

Dayflower and Doveweed. Glyphosate will not control spreading dayflower or doveweed. Spreading dayflower can be controlled with pyrithiobac applied postemergence or with directed herbicide combinations containing MSMA (see Table 10-6). Pyrithiobac or postemergence-directed herbicides should be applied when spreading dayflower shoots are 3 inches long or less. MSMA at rates suitable for over-the-top application will not control it.

Less information is available on doveweed. S-metolachlor appears to control doveweed well if the herbicide is applied and activated before doveweed germination. Paraquat applied with a hooded sprayer is very effective on doveweed. And directed applications of flumioxazin plus MSMA, flumioxazin plus glyphosate, and diuron plus glyphosate appear to be effective. Diuron plus MSMA does not adequately control doveweed.

Florida pusley. This weed, which is usually confined to very sandy fields, is very difficult to control with glyphosate. Glyphosate will control it only if applied when the weed is very small (two leaves or less) and growing conditions are good; multiple applications are often necessary. One should consider using a preplant incorporated or preemergence herbicide in fields where this weed is expected (see Table 10-5).

Morningglory. One application of glyphosate may not adequately control morningglory. A second application of glyphosate or a later application of a conventional directed herbicide is usually needed. For morningglory (except the species tall morningglory) 3 inches or larger, a tank mix of glyphosate plus pyrithiobac is more effective than glyphosate alone. Diuron, fluometuron, or pyrithiobac applied preemergence also will aid in control of morningglory. Trifloxysulfuron, discussed under *Postemergence-Overtop Herbicides – Any Variety*, is very effective on morningglory.

For layby application, conventional chemistries, such as MSMA plus Cobra, diuron, Fierce, flumioxazin, prometryn, and Suprend, will often be more effective on morningglory than glyphosate. However, if one chooses to use glyphosate, the addition of Aim, diuron, Envoke, Fierce, flumioxazin, prometryn, or Suprend would be beneficial.

Hemp sesbania. Hemp sesbania is very difficult to control with glyphosate if the weed is beyond the first-true-leaf stage. Where heavy infestations of hemp sesbania are expected, a preemergence application of Cotoran should be considered. Follow with glyphosate plus pyrithiobac postemergence and then a postemergence-directed application of a conventional herbicide combination. Combinations containing Cobra, Envoke, or Suprend would be good options for the directed application.

Volunteer Roundup Ready corn. Clethodim, fluazifop, quizalofop, or sethoxydim may be applied alone or mixed with glyphosate and applied overtop to control volunteer Roundup Ready corn in Roundup Ready cotton. See labels for these products concerning maximum corn size and use of adjuvants when applying alone or mixed with glyphosate.

Volunteer Roundup Ready soybean. Cotoran applied preemergence will suppress soybean, but it may not provide adequate control. Pyrithiobac alone typically does not adequately control volunteer soybean. However, pyrithiobac applied to three-to-four-trifoliate soybean, followed by a directed application of diuron plus MSMA, prometryn plus MSMA, or Suprend plus MSMA, may provide adequate control. The most effective option to control volunteer soybean is Envoke applied overtop to soybean with less than six trifoliate leaves. Envoke may not control soybean that is taller than about 12 inches.

Nutsedge. Two applications of glyphosate at 0.75 pound a.e. per acre normally control yellow and purple nutsedge. Good results also have been obtained with glyphosate at 0.75 pound a.e. applied overtop, followed by a directed application of MSMA at 2.5 pints per acre or Envoke at 0.15 ounce per acre. In severely infested fields, best results will be obtained with glyphosate plus Envoke overtop or two overtop applications of glyphosate followed by a directed application of Envoke, glyphosate, MSMA, or Suprend. A second directed application of glyphosate or MSMA can be made if needed. Tank-mixing MSMA with glyphosate applied overtop is not recommended.

WEED MANAGEMENT IN GLYTOL LIBERTYLINK COTTON

Varieties are available under both Stoneville and Fibermax brands that contain both the GlyTol and the LibertyLink traits and have excellent tolerance of both glyphosate and glufosinate.

Any brand of glyphosate or glufosinate registered for postemergence application to cotton may be used over the top of GlyTol LibertyLink cotton. Application rates, timing of application, and maximum use rates per season of glyphosate are the same as for Roundup Ready Flex cotton. Glufosinate labels currently allow three applications of 29 fluid ounces, for a seasonal total of 87 ounces. Alternatively, one can apply 30 to 43 fluid ounces once, followed by one more application of 29 fluid ounces, for a seasonal total of 72 ounces. Labels allow glufosinate application from cotton emergence until the early bloom stage. See Table 10-1 for brand names of glufosinate and glyphosate.

Many growers are using glufosinate to control glyphosate-resistant weeds. Glufosinate will play a significant role in cotton weed management for the foreseeable future. It is imperative that growers follow sound resistance management strategies to avoid or delay selection for resistance to glufosinate (see later section on *Herbicide Resistance Management*). In addition to integrating other herbicides into the management program, growers are strongly encouraged to limit glufosinate use to two applications per year.

Timing of Glufosinate Application

Application of glufosinate should be based on weed size rather than crop size. The optimum weed size for treatment with glufosinate varies, depending on the weed species and growing conditions; see label for details. In general, broadleaf weeds should be no more than 4 inches tall. Pigweed species, including Palmer amaranth, and annual grasses should be no more than 3 inches tall. Under dry conditions, pigweed species and annual grasses should be 1 to 2 inches when treated. Optimum timing for the first application generally occurs about two weeks after cotton emergence, with optimum timing of the second application about two weeks after the first application. If Palmer amaranth is larger than 3 inches at the first application, apply 43 oz of glufosinate and repeat with 29 oz in 12 to 14 days.

Time of day of glufosinate application can greatly affect Palmer amaranth control. The impact on control of other common weeds is unknown. **Glufosinate should not be applied sooner than two hours after sunrise nor later than one hour prior to sunset**.

Application Equipment

Glufosinate behaves much like a contact herbicide, so good spray coverage is necessary. Labels recommend flat-fan nozzles, at least 40 pounds pressure per square inch (psi), and a minimum of 10 gallons per acre (gpa) spray volume. Ideally, the spray volume is at least 15 gpa. Drift-reducing nozzles, such as air-induction nozzles, produce larger droplets that may provide less spray coverage than standard flat-fan nozzles. However, general experience has shown that air-induction nozzles are generally acceptable with glufosinate, especially at spray volumes of at least 15 gpa. Nozzles recommended for dicamba application may not be satisfactory with glufosinate.

Need for Soil-Applied Herbicides

Preplant and/or preemergence residual herbicides are strongly encouraged in GlyTol LibertyLink cotton. These herbicides help control annual grasses, pigweed species, and Florida pusley, the common weeds that can be difficult to control with glufosinate. These herbicides will allow greater flexibility in timing of the first glufosinate application. And, most importantly, they will help prevent selection for glufosinate-resistant weeds. See Tables 10-2, 10-4, and 10-5 for information on soil-applied residual herbicides.

Tank Mixes With Glufosinate Applied Overtop

Pyrithiobac (Pyrimax, Pysonex, or Staple LX) can be mixed with glufosinate applied overtop. The typical rate of pyrithiobac would be 1.3 to 2.7 fluid ounces per acre to improve control of larger pigweed species. Pyrithiobac, if activated by rainfall, also will provide residual control or suppression of susceptible species, such as pigweed species. Pyrithiobac does not control biotypes of Palmer amaranth and other species resistant to ALS inhibitors.

S-metolachlor (Brawl, Brawl II, Dual Magnum, Dual II Magnum, Medal, Medal II) can be tank-mixed with glufosinate applied overtop to cotton 3 inches or larger until the early bloom stage. S-metolachlor will not improve control of emerged weeds. If activation is timely, however, it will provide residual control of annual grasses and pigweed species.

Pyrithiobac or S-metolachlor mixed with glufosinate will usually cause some crop injury; see comments concerning pyrithiobac and S-metolachlor use in the section on *Weed Management in Roundup Ready Flex Cotton*. This injury will typically not be sufficient to cause much concern in GlyTol LibertyLink cotton. Do not tank-mix both S-metolachlor and pyrithiobac with glufosinate.

Glyphosate. GlyTol LibertyLink cotton gives growers the option of using both glyphosate and glufosinate, either sequentially or in a tank mix. Tank mixes of these herbicides can be antagonistic (reduced control), especially when the rate of one or both herbicides is reduced. Generally speaking, glyphosate does not impact the activity of glufosinate, but glufosinate can antagonize glyphosate. Whether or not tank mixes should be considered or avoided depends upon the species being targeted. The primary species of concern are grasses and pigweed species, including Palmer amaranth. A tank mix is not recommended for perennial grasses (e.g., bermudagrass or johnsongrass); instead, use glyphosate alone. If annual grasses are the primary targets, glyphosate alone is preferred. However, if one needs to use glufosinate for broadleaf weeds, and grasses larger than 2 inches are present, a tank mix of glyphosate plus glufosinate may be in order. In this case, a full rate of glyphosate is needed. Control of the annual grasses by the tank mix will usually be similar to that with glyphosate alone and better than that with glufosinate alone.

The suitability of a tank mix of glyphosate plus glufosinate on Palmer amaranth or other pigweed species depends upon whether these species are susceptible or resistant to glyphosate. Control of glyphosate-susceptible Palmer amaranth by a tank mixture will be less than control by glyphosate alone but equal to or better than control by glufosinate alone. Differences in control by the tank mixture and glyphosate alone are greater when glyphosate-susceptible weeds are large. Control of larger glyphosate-susceptible weeds by the mixture will be less. Control of glyphosate-resistant Palmer amaranth by the tank mixture will be as good as or better than control by glufosinate alone. Control of glyphosate-resistant common ragweed should be similar with glufosinate alone and glufosinate plus glyphosate.

From a practical standpoint, there are only two situations where one might consider sequential applications of glyphosate and glufosinate. The first situation would be where there is a heavy infestation of annual grasses plus glyphosate-resistant Palmer amaranth, glyphosate-resistant common ragweed, or heavy morningglory. In this case, it would be better to apply glufosinate first simply because weed size is less critical with glyphosate than with glufosinate. If glyphosate is applied first, the glyphosate-resistant weeds will be too large for control by glufosinate at the second application. If the grass control is not adequate, a second application of glyphosate or glyphosate plus glufosinate can be made after new growth is observed on the grasses. Separate these applications by at least seven days. A second situation where sequential applications might be considered would be where one currently has no glyphosate resistance and wishes to alternate mechanisms of action to help prevent resistance. In this situation, it would be better to apply glufosinate first for reasons stated above.

Directed Herbicides in GlyTol LibertyLink

Glufosinate can be directed to GlyTol LibertyLink cotton up to the early bloom stage. Glufosinate can be directed alone or mixed with Aim, diuron, prometryn, or pyrithiobac. Most glufosinate-based management systems will include two overtop applications of glufosinate. Even though the glufosinate label allows up to three applications per season, growers are encouraged to avoid more than two applications per season in order to reduce selection pressure. Glyphosate or any conventional directed herbicide can be directed to GlyTol LibertyLink cotton. See the discussion on tank mixes with glyphosate directed in the section on *Weed Management in Roundup Ready Flex Cotton* and the section on *Postemergence-Directed Herbicides—Any Variety*.

Difficult-to-Control Weeds in Glufosinate-Based Systems

Florida pusley. This weed is typically a problem only on very sandy fields. Glufosinate has limited activity on Florida pusley. Use of a soil-applied herbicide is strongly encouraged on fields where this weed is expected (see Table 10-5).

Pigweed species. Pigweed species, including Palmer amaranth, can be controlled by glufosinate. However, timing of application to pigweed species is usually critical, especially under dry conditions. A preplant and/or preemergence herbicide is recommended for fields with a history of pigweed. Use of a preemergence herbicide will make the timing of the first application of glufosinate much less critical. Pyrithiobac (Pyrimax, Pysonex, or Staple LX) can be mixed with glufosinate to improve control of emerged pigweed. However, Palmer amaranth resistance to pyrithiobac is common.

Goosegrass and other annual grasses. In general, glufosinate is more effective on broadleaf weeds than grasses. Timing of application to grasses, and especially goosegrass, is critical. Two applications of glufosinate are normally needed to control or suppress goosegrass. A soil-applied herbicide (see Table 10-4) can help tremendously in controlling goosegrass and other annual grasses. S-metolachlor mixed with glufosinate will not improve control of emerged grasses, but it can provide residual control. This effect can be important in control of goosegrass as this grass tends to emerge a little later than most other annual grasses.

Glufosinate should not be tank-mixed with postemergence grass-control herbicides. These tank mixes are very antagonistic (reduced grass control). If additional grass control is needed, any of the grass-control herbicides (clethodim, fluazifop, quizalofop, sethoxydim) can be applied three days before glufosinate or seven days after glufosinate.

Glyphosate is more effective on grasses than glufosinate. Glyphosate can be mixed with glufosinate or applied sequentially with glufosinate. See above discussion on the use of glyphosate in conjunction with glufosinate.

Nutsedge. Glufosinate will significantly burn nutsedge, but the weed typically grows back. Adequate control of nutsedge can usually be obtained with glufosinate followed by Envoke applied overtop or glufosinate followed by one or two directed applications of MSMA or a directed application of Suprend. See comments on use of Envoke under *Postemergence-Overtop Herbicides—Any Variety*. Do not mix Envoke with glufosinate. Glyphosate is generally more effective on nutsedge than glufosinate. See above discussion on the use of glyphosate in conjunction with glufosinate.

Dayflower and Doveweed. Glufosinate will not control spreading dayflower. This weed can be controlled with pyrithiobac (Pyrimax, Pysonex, or Staple LX) applied postemergence at 2.6 to 3.8 fluid ounces per acre or directed herbicide combinations containing MSMA (see Table 10-6). Postemergence herbicides should be applied when spreading dayflower shoots are 3 inches long or less.

Glufosinate has some activity on doveweed. However, the weed often recovers and grows back. Paraquat, applied under a hood, is very effective on doveweed. Preliminary results indicate that S-metolachlor is very effective if applied before doveweed germination. Flumioxazin plus MSMA directed is also effective.

WEED MANAGEMENT IN ROUNDUP READY XTENDFLEX COTTON

XtendFlex cotton has tolerance to glyphosate, glufosinate, and dicamba. Any of the programs discussed above under *Weed Management in Roundup Ready Flex Cotton* and under *Weed Management in Glytol LibertyLink Cotton* can be used in XtendFlex cotton. In addition, registered brands of dicamba can be applied.

Two brands of dicamba are currently registered for use in XtendFlex cotton—Engenia and XtendiMax. Growers are strongly encouraged to use only these brands as they are less volatile than other brands. Use of these brands will reduce, but not completely eliminate, the potential for vapor drift. In addition, a good preemergence herbicide program is strongly recommended. See discussion on soil-applied herbicides under the section *Weed Management in Roundup Ready Flex Cotton*.

Application Timing

Engenia or XtendiMax can be applied any time prior to planting, preemergence after planting, and postemergence. Applied as part of the preplant burndown program, dicamba can help with control of weeds such as glyphosate-resistant horseweed, wild radish, and cutleaf eveningprimrose (see discussion under *Burndown in No-Till or Strip-Till Cotton*). An advantage of XtendFlex cotton is that there is no waiting period between preplant application and planting. However, a timely burndown application at least two weeks ahead of planting is still encouraged.

Preemergence application of dicamba is generally discouraged. Although dicamba can give good residual control of broadleaf weeds, the control is short-lived (14 days or less), and it is quite inconsistent. Preemergence application of dicamba should be considered only in situations where paraquat is not a good option. An example might be large horseweed not adequately controlled by an earlier burndown application.

Engenia or XtendiMax can be applied postemergence any time from cotton emergence until seven days prior to harvest. Dicamba should be applied postemergence no more than twice per season. And those applications should be timely; broadleaf weeds should be less than 4 inches tall. For various reasons, application after cotton is more than about 12 to 16 inches tall should be avoided.

Tank Mixtures

Only certain herbicides are allowed to be tank-mixed with Engenia or XtendiMax. Permissible tank mixtures with Engenia or XtendiMax can be found online at www.engeniatankmix.com or www.xtendimaxapplicationrequirements.com. Note that some tank mixes require the use of a drift reduction agent.

Preplant. Engenia or XtendiMax can be mixed with selected brands of glyphosate, Rowel, Sharpen (Engenia only), or Valor and applied preplant. If mixing with Rowel, Sharpen, or Valor, the waiting periods for those products still apply (see Table 10-2).

Preemergence. Engenia or XtendiMax can be mixed with selected brands of glyphosate, Caparol, selected brands of diuron, selected brands of pendimethalin, Reflex, Staple, Warrant, and Warrant Ultra (XtendiMax only) and applied preemergence. Engenia or XtendiMax cannot be mixed with paraquat, Brake, Brake F16, or Cotoran.

Postemergence. Engenia or XtendiMax can be mixed with selected brands of glyphosate, selected brands of clethodim, Staple, or Warrant. Engenia can also be mixed with Outlook. Neither Engenia nor XtendiMax can be mixed with s-metolachlor, glufosinate, Envoke, fluazifop, quizalofop, or sethoxydim. No insecticides can be mixed with XtendiMax. Only the insecticides Avenger Bold (imidacloprid + bifenthrin) or Radiant (spinetoram) can be mixed with Engenia.

WEED MANAGEMENT IN ENLIST COTTON

Certain Phytogen varieties, designated as W3FE, carry the Enlist trait and are tolerant of 2,4-D, glyphosate, and glufosinate. In contrast to WRF varieties, those varieties designated as W3FE have complete tolerance of glufosinate. Any of the programs discussed above under *Weed Management in Roundup Ready Flex Cotton* and under *Weed Management in Glytol LibertyLink Cotton* can be used in Enlist cotton. In addition, Enlist One (contains choline salt of 2,4-D) and Enlist Duo (contains glyphosate plus the choline salt of 2,4-D) can be applied. These are the only brands containing 2,4-D that can be applied to Enlist cotton.

Application Timing

Enlist One and Enlist Duo can be applied any time prior to planting, preemergence after planting, and postemergence. 2,4-D is already widely used in preplant burndown. An advantage of Enlist cotton is that there is no waiting period between preplant application and planting. However, a timely burndown application at least two weeks ahead of planting is still encouraged.

A good preemergence herbicide program should be used in Enlist cotton regardless of the postemergence program. See discussion on soil-applied herbicides under the section *Weed Management in Roundup Ready Flex Cotton*.

Enlist One or Enlist Duo can be applied postemergence any time from cotton emergence until the midbloom stage. Apply postemergence no more than twice per season. Separate applications by at least 12 days. Weeds, especially Palmer amaranth, should be no more than 3 to 4 inches tall.

Tank Mixtures

No herbicides are currently approved for tank-mixing with Enlist Duo. Only certain herbicides are allowed to be tank-mixed with Enlist One. Permissible tank mixtures with Enlist One can be found online at www.enlist.com/en/approved-tank-mixes/enlist-one. Drift reduction agents are not required with Enlist One tank mixes, although certain ones are approved for application; see approved products on the above website.

Preplant. No tank mixes with Enlist Duo are approved. For burndown, Enlist One can be mixed with Valor, but the waiting interval between Valor application and planting still applies (see Table 10-2).

Preemergence. Preemergence application of either Enlist product is discouraged unless needed to kill weeds, such as horseweed, not adequately controlled by an earlier burndown application.

Enlist One can be mixed with specified brands of glyphosate, Cotoran, Direx, Prowl H_2O, Reflex, Staple, Warrant, and Warrant Ultra and applied preemergence.

Postemergence. Enlist Duo cannot be mixed with any other herbicides or insecticides for postemergence application. Enlist One can be applied postemergence in mixture with specific brands of glyphosate, specific brands of glufosinate, Dual Magnum, Staple, and Warrant. Approved insecticides for mixing with Enlist One include Acephate 97UP, Centric, Dimethoate, Intrepid Edge, Radiant, and Transform.

WEED MANAGEMENT IN PHYTOGEN WIDESTRIKE COTTON

Varieties with the WideStrike trait (designated WRF) have excellent tolerance of glyphosate. Any of the programs discussed under *Weed Management in Roundup Ready Flex Cotton* can be used in WideStrike cotton.

WideStrike cotton also has incomplete tolerance of glufosinate. According to the Environmental Protection Agency (EPA), glufosinate herbicide can be applied to WideStrike cotton. However, **the grower is liable for any crop injury resulting from the application**. Neither glufosinate producers nor Phytogen warrant the use of glufosinate on WideStrike cotton.

Some injury can be expected when glufosinate is applied to WideStrike cotton. The injury is basically leaf burn, and can range from very minor to rather significant. The injury is contact in nature, and the crop generally recovers. Most research in North Carolina has not shown significant yield reduction of WideStrike cotton when glufosinate is used as described below. However, some exceptions have occurred.

If glufosinate is used in WideStrike cotton, only two applications at 29 fluid ounces each are suggested. Applications should be based on weed size. The first application is typically needed about 14 days after planting, and the second application is needed about two weeks after the first application. Rates in excess of 29 fluid ounces are discouraged unless needed for weed control; higher rates cause more foliar burn. Ammonium sulfate can increase weed control by glufosinate. However, ammonium sulfate can increase WideStrike cotton response to glufosinate and its use is generally discouraged. In addition, application after the eight-leaf stage of WideStrike cotton should be avoided. Application near first bloom or later may cause unacceptable crop injury and yield reduction. S-metolachlor, acetochlor, or insecticides added to glufosinate usually increase WideStrike cotton injury, and there is some evidence that these mixtures may reduce yield.

POSTEMERGENCE-OVERTOP HERBICIDES—ANY VARIETY

Pyrithiobac (Pyrimax, Pysonex, Staple LX) can be applied overtop of cotton from the cotyledonary stage until 60 days before harvest. Two applications per year are allowed as long as the total applied per season does not exceed 5.1 fluid ounces (see comments in Table 10-2).

If applied in a timely manner, pyrithiobac controls many broadleaf weeds (Table 10-7). Note that pyrithiobac applied postemergence does not adequately control lambsquarters, ragweed, sicklepod, spurge, tall morningglory, or tropic croton. Timing of application is critical. Most susceptible broadleaf weeds should not be taller than 3 to 4 inches. Prickly sida must be 1 inch or less for acceptable control. Palmer amaranth should be 2 inches or less. Carefully read the label for specific recommendations on weed size. Palmer amaranth resistant to pyrithiobac is common across North Carolina.

Tank mixes of pyrithiobac with clethodim, fluazifop, quizalofop, or sethoxydim are not recommended because antagonism (reduced grass control) is often observed. Pyrithiobac labels allow a tank mix with quizalofop for control of johnsongrass, but the label discourages tank-mixing with other grass-control herbicides or application to other grass species.

When making sequential applications of pyrithiobac and a postemergence grass-control herbicide, apply the pyrithiobac at least three days before or one day after application of the grass-control herbicide. Longer intervals between applications of the two herbicides are preferred.

Trifloxysulfuron (Envoke) can be applied overtop cotton with a minimum of five leaves up to 60 days prior to harvest (see comments in Table 10-2). In cotton larger than about 10 inches, directed or semi-directed application may improve spray coverage on weeds below the crop canopy. Envoke controls or suppresses nutsedge plus several broadleaf weeds (see Tables 10-6 and 10-7). For best control, weeds should be 2 to 4 inches tall. Note that Envoke does not control jimsonweed, prickly sida, spreading dayflower, or spurred anoda, and it is not adequately effective on tropic croton. Control of Palmer amaranth is often inadequate.

Pyrithiobac and Envoke have the same mechanism of action. Palmer amaranth resistant to pyrithiobac will not be controlled by Envoke. Palmer amaranth resistant to both pyrithiobac and Envoke is common in North Carolina.

Cotton will sometimes be injured by Envoke applied overtop. Injury is expressed as yellowing in the growing point and shortened internodes. Some degree of crop response can almost always be expected. In most cases, the injury is relatively minor and the crop recovers. On occasion, however, moderate to severe injury has been observed. Smaller cotton appears to be injured more than larger cotton. Other factors contributing to crop injury are unknown. However, growers are encouraged to not apply Envoke to cotton with fewer than five leaves (seven to eight leaves are preferred) and to not apply the herbicide to cotton under stress from wet or dry weather or thrips. Also, carefully follow label directions for adjuvant usage. Tank-mix Envoke only with those insecticides specifically mentioned on the Envoke label. Tank mixes of Envoke with clethodim, fluazifop, quizalofop, or sethoxydim should also be avoided. Separate applications of Envoke and the grass-control herbicides by at least three days if the grass-control herbicide is applied first or five days if Envoke is applied first.

Grass-control herbicides. Clethodim, fluazifop, quizalofop, and sethoxydim can be applied overtop cotton from emergence through midseason (see brands in Table 10-1 and comments in Table 10-2). These products control annual and perennial grasses but are ineffective on nutsedge and broadleaf weeds (see Table 10-6). All of these products are safe on cotton and are effective when applied to small grasses under good growing conditions. However, clethodim and sethoxydim tend to be more effective over a range of annual grass species and environmental conditions. Clethodim, fluazifop, and quizalofop tend to be more effective on perennial grasses than sethoxydim. When using any of these herbicides, follow label directions for application rates, application methods, use of adjuvants, and optimum grass size for treatment. Tank-mixing broadleaf herbicides such as pyrithiobac or Envoke with these postemergence grass-control herbicides is not recommended.

POSTEMERGENCE-DIRECTED HERBICIDES—ANY VARIETY

Several herbicide combinations are available for directed application to any variety of cotton (see Table 10-2). These postemergence-directed herbicide combinations are primarily for annual broadleaf weeds and nutsedge. See Table 10-8 for broadleaf weed response. MSMA in the combinations will also control annual grasses 1.5 to 2 inches tall or less. Except for MSMA and Cobra plus MSMA, these directed options also provide some residual control of small-seeded broadleaf weeds. S-metolachlor can be mixed with some of the herbicide combinations. See the herbicide labels for minimum cotton size to treat, maximum weed size, application directions and precautions, and rotational restrictions.

PERENNIAL BROADLEAF WEEDS

Perennial broadleaf weeds, such as horsenettle, trumpetcreeper, common milkweed, and hemp dogbane, can be problems in no-till situations, although the problem has been greatly reduced through use of glyphosate in tolerant varieties. Soil-applied herbicides will not control perennial broadleaf weeds and, with the exception of horsenettle, conventional postemergence-directed herbicides are ineffective. Acceptable control of horsenettle has been obtained with postemergence-directed herbicide combinations containing MSMA. Two applications of MSMA or a combination containing MSMA will usually be needed.

Perennial broadleaf weeds can be suppressed or controlled with multiple applications of glyphosate. Later applications are generally more effective on perennials, and two applications are more effective than one. Adequate spray coverage on low-growing perennials, such as trumpetcreeper and horsenettle, may require directed application. Harvest-time applications of glyphosate are also an option to suppress perennial weeds for the following year (see *Preharvest Herbicide Application*).

Curly dock is best controlled by a preplant application of thifensulfuron plus tribenuron (see Tables 10-1 and 10-3).

Perennial broadleaf weeds can be suppressed or controlled in corn or Roundup Ready soybeans grown in rotation with cotton. In corn, an early postemergence application of dicamba alone or mixed with a nicosulfuron-containing herbicide followed by a layby application of dicamba is most effective. Alternatively, glyphosate or a tank mix of 2,4-D plus dicamba can be applied to infested spots after corn harvest. In Roundup Ready soybeans or Roundup Ready corn, two postemergence applications of glyphosate will adequately suppress perennial broadleaf weeds.

PREHARVEST HERBICIDE APPLICATION

Preharvest herbicide applications are of questionable value in most cases. Desiccating mature weeds likely will not increase harvesting efficiency nor reduce harvesting losses, and the impact on weed seed production is minimal. The major exception would be fields heavily infested with vining weeds such as morningglory. Problems with extraneous green matter in harvested cotton are probably overstated. Lint staining from weeds has not been a significant problem in spindle-picked cotton in North Carolina. Desiccating weeds will more likely increase rather than decrease trash in cotton because gins can remove green plant parts more easily than finely ground, desiccated plant parts. However, if present in large quantities, extraneous green matter can increase the potential for overheating, rot, and stain if modules are not properly monitored.

Annual Weeds

Carfentrazone (Aim) is registered for use as a defoliant. Good desiccation of morningglory and cocklebur has been observed with Aim if spray coverage is good. Results on pigweed species have been inconsistent but generally not acceptable. Aim will not desiccate grasses or sicklepod. See the Aim label concerning use of crop oil concentrate.

Glyphosate can be applied to glyphosate-tolerant varieties seven or more days ahead of harvest regardless of the percentage of open bolls.

Another option is paraquat applied after cotton defoliation. In this program, the cotton is defoliated as normal. After at least 75 to 80 percent of the bolls are open, the remaining bolls expected to be harvested are mature, and most of the cotton leaves have dropped, apply paraquat at 1.9 pints of a 2 lb/gal formulation or 1.3 pints of a 3 lb/gal formulation (see chapter 12, "Cotton Defoliation," for discussion on determining boll maturity). Broadcast the paraquat in a minimum of 20 gallons of water per acre and add 1 pint of nonionic surfactant per 100 gallons of water. Wait five days before picking, and then pick as soon as possible. If spray coverage is good, paraquat will desiccate most annual weeds.

Perennial Weeds

Glyphosate can be applied in the fall to control or suppress perennial weeds for the following year. For johnsongrass control, glyphosate at a rate of 0.75 to 1.5 pounds a.e. per acre may be tank-mixed with the defoliant. Apply when at least 60 percent of the bolls are open. Alternatively, glyphosate may be applied after defoliation. Application after defoliation may be preferred in rank cotton to improve spray coverage. In addition, a separate application of glyphosate allows treatment of only the infested areas of a field.

For other perennial weeds, such as bermudagrass, nutsedge, trumpetcreeper, horsenettle, common milkweed, and hemp dogbane, glyphosate-defoliant tank mixes are not recommended. If you need to control these weeds, defoliate the cotton as usual. Apply the glyphosate after most of the cotton leaves have dropped. Suggested application rates are 2.25 pounds a.e. per acre for nutsedge, trumpetcreeper, common milkweed, and bermudagrass, and 3 pounds a.e. for horsenettle and hemp dogbane. To reduce costs, spot-spray only infested areas.

For tall-growing weeds, such as johnsongrass, common milkweed, and hemp dogbane, the glyphosate should be applied after most of the cotton leaves have dropped but before harvest. The glyphosate can be applied to low-growing weeds, such as bermudagrass, nutsedge, horsenettle, and trumpetcreeper, after most of the cotton leaves have dropped and either before or after harvest. Glyphosate should be applied at least 7 to 10 days before the first killing frost.

HERBICIDE RESISTANCE MANAGEMENT

Herbicide resistance has become a serious problem in North Carolina. Horseweed resistant to glyphosate is very common across eastern North Carolina and is becoming a problem in the NC piedmont. Common ragweed resistant to glyphosate exists in several northeastern counties. Ryegrass resistant to glyphosate occurs sporadically across the NC southern piedmont. And, of major significance, glyphosate-resistant Palmer amaranth is now widespread across the state. Based on a 2010 statewide survey, 95 percent of the Palmer amaranth populations contained individuals resistant to both glyphosate and ALS inhibitors such as pyrithiobac and Envoke.

In previous years, growers with herbicide-resistant weeds were fortunate to have new herbicides (specifically, new mechanisms of action) come to the marketplace before the problem became overwhelming. That will not be the case in the foreseeable future; new mechanisms of action are simply not on the horizon. XtendFlex varieties, resistant to dicamba, glyphosate, and glufosinate, and Enlist varieties, resistant to 2,4-D, glyphosate, and glufosinate, will certainly be helpful in managing resistant weeds, but herbicides used within these varieties are not new mechanisms of action. It is imperative that growers take herbicide resistance management very seriously in an attempt to maintain the usefulness of the products currently available. This advice is particularly true for glufosinate and the PPO inhibitors. Glufosinate is being widely used in cotton, and PPO inhibitors are widely used in cotton and all the major rotational crops. Growers can ill afford to select for resistance to these herbicides. Common ragweed resistant to PPO inhibitors has been confirmed in North Carolina, and Palmer amaranth resistant to PPO inhibitors is highly suspected.

What Causes Resistance?

Herbicides do not cause resistance. Rather, herbicides select for resistance that may naturally occur in the weed population. Greater reliance on a particular herbicide, or group of herbicides with the same mechanism of action, puts greater selection pressure on any resistant individuals that may be in the population. A shift to conservation tillage and a corresponding decrease in cultivation have led to greater reliance on herbicides and greater potential problems with resistance.

Resistance Management Strategies

There are two prerequisites for resistance. First, one or more individuals possessing genes conferring resistance must be present in the population. Second, selection pressure resulting from extensive use of a herbicide to which these rare individuals are resistant must be exerted on the population. Growers have no way to know if a few plants carrying resistance are present on their farm. Hence, the only way to prevent a buildup of resistant plants is to use management systems that reduce selection pressure on any resistant individuals that may be present.

Every acre of cotton in North Carolina is planted to glyphosate-resistant varieties, and more than 99 percent of the acreage is also resistant to glufosinate. Both herbicides are widely used. A high percentage of the corn and soybean acreage is also planted to Roundup Ready varieties, and acreage of glufosinate-resistant soybean is increasing. In many cases, growers have relied almost exclusively on glyphosate or glufosinate for weed control. Extensive reliance on a single mechanism of action (the mechanism by which the herbicide kills susceptible plants) over that much acreage puts tremendous selection pressure on any resistant weeds that may be in the population. Use of PPO-inhibiting herbicides, such as flumioxazin and fomesafen, has increased dramatically in cotton and other crops with the greater occurrence of glyphosate-resistant biotypes. Commonly used PPO inhibitors include acifluorfen, carfentrazone, flumiclorac, flumioxazin, fomesafen, lactofen, pyraflufen, saflufenacil, and sulfentrazone. There is concern that use of these herbicides repeatedly will result in selection for PPO-resistant biotypes. Similarly, reliance on glufosinate in glufosinate-tolerant cotton or soybean as the primary mechanism of action will select for resistance to glufosinate. It is absolutely essential that herbicide programs be diverse in mechanism action in order to reduce selection pressure for resistant weeds.

The key component of a resistance management strategy is to integrate herbicides having different mechanisms of action into the cropping system. Mechanisms of action for cotton herbicides are included in Table 10-1 as an aid to growers. An effective resistance management strategy in cotton will incorporate herbicides having at least three (preferably more) different mechanisms of action. In addition, growers are encouraged to minimize their reliance on ALS-inhibiting herbicides as these chemistries are highly vulnerable to resistance.

Cotton growers can incorporate the recommended diversity in mechanisms of action into a glyphosate-based or a glufosinate-based management program by using soil-applied residual herbicides, tank-mixing another herbicide with glyphosate or glufosinate applied postemergence, and using alternatives to glyphosate or glufosinate or at least a tank mix with glyphosate or glufosinate at layby. Use of full rates of glyphosate or glufosinate, even in tank mixes, is encouraged. Crop rotation can aid in resistance management if herbicide mechanisms of action for the rotational crop are wisely selected. Where practical, cultivation would also be a very effective component of a resistance management strategy. A heavy cover crop residue will also help suppress weeds.

Glyphosate-Resistant Horseweed

Glyphosate-resistant horseweed (also called marestail) is now very common across eastern North Carolina and is becoming common in the NC piedmont. Continued spread is expected as seed of horseweed are easily moved by wind and equipment. Horseweed is a problem in strip-till and no-till systems, and growers planting no-till or strip-till cotton, especially in eastern North Carolina, should assume that horseweed present in fields is resistant to glyphosate.

Horseweed germinates primarily in the fall, but additional plants may emerge in late spring. Plants emerging in the fall will be in a rosette stage and large enough for easy identification by early winter. Pictures of small horseweed can be found at oak.ppws.vt.edu/~flessner/weedguide/erica.htm.

An early preplant burndown program is encouraged for horseweed. Glyphosate-resistant horseweed can be controlled by tank mixes of glyphosate plus 0.95 pound a.e. of 2,4-D (2 pints of typical 3.8 lb a.e./gal formulation) or glyphosate plus 0.5 pint of dicamba (0.25 lb a.e. of typical 4 lb a.e./gal products). Engenia or XtendiMax labels specify 12.8 or 22 oz, respectively, which gives 0.5 lb a.e./acre. Mixtures with dicamba may perform more consistently than 2,4-D mixtures, although 2,4-D has typically worked well in North Carolina. Application in March is recommended, or the first week in April at the latest. Control failures are usually related to later applications. The tank mix with 2,4-D should be applied at least 30 days ahead of planting (see comments in Table 10-2). Cotton planting must be delayed at least 21 days after the accumulation of 1 inch of rainfall following dicamba application. This requirement often means a four-to-six-week delay between dicamba application and planting. Although injury to cotton is possible from either 2,4-D or dicamba applied in a cold, dry spring, research to date in North Carolina has shown no problems when the above guidelines were followed. There is no waiting period between Engenia or XtendiMax application and planting of XtendFlex varieties, and there is no waiting period between Enlist One or Enlist Duo application and planting of Enlist varieties.

Spring-germinating horseweed will not be controlled by previously applied 2,4-D or dicamba. Flumioxazin included in a tank mix of glyphosate plus 2,4-D or glyphosate plus dicamba will reduce problems with late-emerging horseweed. Cotoran applied preemergence is the best option to control late-emerging horseweed in the crop. Paraquat should be included with the Cotoran to kill emerged weeds at time of planting.

Another option to control glyphosate-resistant horseweed is a mixture of glyphosate plus Sharpen. Sharpen is very effective on emerged horseweed and it gives residual control of later-emerging horseweed. Dicamba or 2,4-D can also be added to the mixture. There is a long waiting interval between Sharpen application and planting. The Sharpen label specifies a waiting interval of 42 days plus accumulation of 1 inch of rainfall.

Glufosinate will also control horseweed if applied when daytime temperatures exceed 75°F. Glufosinate is therefore an option to control emerged horseweed at time of planting. If one is planning to use a glufosinate-based system for Palmer amaranth control, an alternative to glufosinate for at-planting burndown is encouraged.

Options to control emerged glyphosate-resistant horseweed in emerged cotton are limited. Glufosinate, glufosinate plus Enlist One, glyphosate plus Engenia, glyphosate plus XtendiMax, glyphosate plus Enlist One, and Enlist Duo are options in the appropriate varieties. Smaller horseweed is more easily killed.

Glyphosate-Resistant Palmer Amaranth

Palmer amaranth is the most troublesome weed in cotton across much of the Cotton Belt. Growers must undertake both an aggressive program to control existing resistant populations and a proactive program to reduce further selection for resistant biotypes.

Suggested herbicide programs are in Table 10-10. For conventional tillage systems, trifluralin or pendimethalin are effective on Palmer amaranth if shallowly and uniformly incorporated. In no-till or strip-till systems, an early preplant burndown application of glyphosate plus either 2,4-D or dicamba is suggested for good burndown of a wide range of species, including glyphosate-resistant horseweed, wild radish, and cutleaf eveningprimrose. Flumioxazin should be included in this burndown application. The flumioxazin will control weeds germinating after the burndown application. And, if applied no more than three to four weeks prior to planting, the flumioxazin will control Palmer amaranth for about two weeks after cotton planting. This control can be very important if timely rainfall is not received following planting to activate the preemergence herbicides.

Regardless of the tillage system, a strong preemergence program is needed. Apply one of the preemergence options in Table 10-10 as soon as possible after planting. In no-till or strip-till programs, paraquat should be included in the preemergence application to control any emerging Palmer amaranth or other weeds. Warrant is very effective on Palmer amaranth and is usually safe for cotton. Under conditions that cause delayed emergence of cotton, Warrant may cause stunting and uneven growth. Fomesafen is also very effective on Palmer amaranth, but it can injure cotton if heavy rainfall is received very soon after planting, or if the first rainfall occurs after cotton emergence and soil is splashed onto the cotton leaves. A combination of Warrant at the full rate (3 pt/acre) plus a reduced rate of fomesafen (10 to 12 fl oz/acre) or a three-way combination of Warrant (2 pt/acre) plus diuron (1 pt/acre) plus fomesafen (10 oz/acre) has been very effective in research trials, and the potential for fomesafen injury is reduced. Fomesafen plus diuron has also been an effective combination. Fomesafen should be used only on sandy Coastal Plain soils; do not use fomesafen preemergence on clay soils.

Follow the preemergence application with one of the postemergence options listed in Table 10-10. Palmer amaranth will ideally be no more than 1 to 2 inches at the first application. Optimal timing for the first postemergence application often occurs about 14 days after planting. A second postemergence application should be made when the next flush of Palmer amaranth is 1 to 2 inches tall. This event typically occurs about 14 days after the first application. Another residual herbicide may be included in the second application if the field has a history of heavy Palmer amaranth infestations. The second residual is definitely in order for growers who do not plan on a layby application. Many growers are trying to avoid layby applications, but research has clearly shown these applications have a place in Palmer amaranth management systems.

Many of the herbicides listed in Table 10-10 are not effective on Blackland soils (or soils with more than about 5 percent organic matter). Warrant, flumioxazin, pyrithiobac, and S-metolachlor are effective in Blackland soils.

In addition to the herbicide programs in Table 10-10, growers need to strive for zero tolerance of Palmer amaranth seed production. Follow effective programs in all crops rotated with cotton. Hand-removal of escapes is worth the effort. For crops harvested early, such as corn or tobacco, do not allow late-emerging weeds to produce seed. A postharvest application of paraquat is very effective on Palmer amaranth and can substantially help reduce the seedbank for future years.

Glyphosate-Resistant Common Ragweed

Common ragweed resistant to glyphosate is present in several counties in northeastern North Carolina and appears to be spreading. Fortunately, this weed is not as difficult to manage as glyphosate-resistant Palmer amaranth. Common ragweed emerges earlier than many other summer annual broadleaf weeds. Flumioxazin applied early burndown in combination with glyphosate plus 2,4-D or glyphosate plus dicamba will provide residual control of early emerging common ragweed. Brake F16, Cotoran, or fomesafen plus diuron applied preemergence are effective (Table 10-5). In no-till or strip-till systems, flumioxazin applied preplant burndown will also assist in control. Common ragweed can be controlled postemergence with glufosinate followed as needed by Envoke. Most of the conventional directed herbicide combinations are also effective (Table 10-8). Engenia or XtendiMax in XtendFlex cotton and Enlist One or Enlist Duo in Enlist cotton are also effective on common ragweed.

Table 10-1. Brand Names and Formulations for Active Ingredients Mentioned in Chapter 10

Active ingredient(s)	Brand name(s)	Concentration	Formulation	Mechanism of Action[1]
acetochlor	Warrant	3 lb a.i./gal	CS	15
acetochlor + fomesafen	Warrant Ultra	2.82 + 0.63 lb a.i./gal	CS	15 + 14
carfentrazone	Aim	2 lb a.i./gal	EC	14
clethodim	Arrow, AgriStar Clethodim, Avatar S2, Dakota, Grassout Max, Intensity, Section, Select, Shadow, Tide Clethodim, Volunteer, Willowood Clethodim	2 lb a.i./gal	EC	1
	Intensity One, Select Max, Tap Out	0.97 lb a.i./gal	EC	1
2,4-D choline salt	Enlist One	3.8 lb a.e./gal	S	4
2,4-D choline salt plus glyphosate	Enlist Duo	1.6 + 1.7 lb a.e./gal	S	4 + 9
2,4-D dimethylamine salt	Numerous brands and concentrations		S	4
2,4-D 2-ethylhexyl ester	Numerous brands and concentrations		EC	4
dicamba, BAPMA salt	Engenia	5.0 lb a.e./gal	S	4
dicamba, diglycolamine salt	Clarity, Clash, Detonate, Dicamba HD, Dicash DGA-4, Sterling Blue, Strut	4 lb a.e./gal	S	4
	XtendiMax with VaporGrip Technology, Dupont Fexapan with VaporGrip Technology	2.9 lb a.e./gal	S	4
dicamba + 2,4-D	Burnmaster	1.0 + 3.07 lb a.e./gal	EC	4 + 4
	Spitfire	0.5 + 3.07 lb a.e./gal	EC	4 + 4
dimethenamid-P	Outlook	6 lb a.i./gal	EC	15
diuron	Diuron 80, Diuron 80DF, Diuron 80WDG, Karmex DF, Parrot DF	80%	DF	7
	Direx 4L, Diuron 4L, Parrot 4L, Sekor 4L, SuperDi 4L	4 lb a.i./gal	F	7
diuron + linuron	Layby Pro	2 + 2 lb a.i./gal	F	7 + 7
fluazifop-P-butyl	Fusilade DX	2 lb a.i./gal	EC	1
flumiclorac	Resource	0.86 lb a.i./gal	EC	14

continued

Table 10-1. Brand Names and Formulations for Active Ingredients Mentioned in Chapter 10 (continued)

Active ingredient(s)	Brand name(s)	Concentration	Formulation	Mechanism of Action[1]
flumioxazin	Outflank, Panther, Rowel, Valor SX, Warfox	51%	WDG	14
	Panther SC	4 lb a.i./gal	SC	14
flumioxazin + pyroxasulfone	Fierce	33.5 + 42.5%	WDG	14 + 15
fluometuron	Cotoran 4L	4 lb a.i./gal	F	7
fluridone	Brake	1.2 lb a.i./gal	F	12
fluridone + fomesafen	Brake F16	1.2 + 1.5 lb a.i./gal	F	12 + 14
fomesafen	Dawn, Foma 2.0, Fomesafen 2SL, Reflex, Ringside, Shafen, Top Gun, Willowood Fomesafen 2SL	2 lb a.i./gal	S	14
	Battle Star, Foma 1.88, Rumble, Willowood Fomesafen 1.88SL	1.88 lb a.i./gal	S	14
	Sinister	2.87 lb a.i./gal	S	14
fomesafen + glyphosate	Flexstar GT3.5	0.56 + 2.26 lb a.i./gal	S	14 + 9
glufosinate	Agri Star Surmise, Cheetah, Forfeit 280, Interline, Liberty 280 SL, Refer 280 SL, Willowood Glufosinate 280SL	2.34 lb a.i./gal	S	10
glyphosate	See Table 10-9	various	S	9
glyphosate + S-metolachlor	Sequence	2.5 lb a.e./gal + 3 lb a.i./gal	EC	9 + 15
lactofen	Cobra	2 lb a.i./gal	EC	14
MSMA	MSMA-6 Plus	6 lb a.i./gal	S	17
	MSMA 6.6	6.6 lb a.i./gal	S	17
paraquat	Gramoxone SL	2 lb a.i./gal	S	22
	Bonedry, Devour, Firestorm, Helmquat, Paraquat Concentrate, Para-Shot, Parazone, Quik-Quat, Willowood Paraquat	3 lb a.i./gal	S	22
pendimethalin	Prowl H2O, Satellite HydroCap	3.8 lb a.i. /gal	CS	3
	Acumen, Framework 3.3EC, Helena Pendimethalin, Pendipro, Prowl 3.3 EC, Stealth	3.3 lb a.i./gal	EC	3
prometryn	Caparol, Cotton-Pro	4 lb a.i./gal	F	5
prometryn + trifloxysulfuron	Suprend	79.3% prometryn + 0.7% trifloxysulfuron	DF	5 + 2

continued

Table 10-1. Brand Names and Formulations for Active Ingredients Mentioned in Chapter 10 (continued)

Active ingredient(s)	Brand name(s)	Concentration	Formulation	Mechanism of Action[1]
pyraflufen	ET	0.208 lb a.i./gal	EC	14
pyrithiobac	Pyrimax, Pysonex, Staple LX	3.2 lb a.i./gal	S	2
pyroxasulfone	Zidua	85%	WDG	15
quizalofop P-ethyl	Assure II, Se-cure, Targa	0.88 lb a.i./gal	EC	1
rimsulfuron + thifensulfuron	Leadoff	16.7 + 16.7 %	WDG	2 + 2
	Crusher	25 + 25%	WDG	2 + 2
S-metolachlor	Brawl, Charger Basic, Dual Magnum, Medal	7.62 lb a.i./gal	EC	15
	Brawl II, Dual II Magnum, Medal II	7.64 lb a.i./gal	EC	15
S-metolachlor + fomesafen	Prefix	4.34 + 0.95	EC	15 + 14
saflufenacil	Sharpen	2.85 lb a.i./gal	SC	14
sethoxydim	Poast	1.5 lb a.i./gal	EC	1
	Nufarm Sethoxydim SPC, Poast Plus	1.0 lb a.i./gal	EC	1
thifensulfuron + rimsulfuron	Leadoff	16.7 + 16.7%	WDG	2 + 2
	Crusher	25 + 25%	WDG	
thifensulfuron + tribenuron	Audit 1:1, Edition Broadspec, FirstShot, Rapport BroadSpec	25 + 25%	WDG	2 + 2
	Harmony Extra	33.33 + 16.67%	WDG	2 + 2
	Nimble, Treaty Extra, T-Square, Volta Extra	50 + 25%	WDG	2 + 2
trifloxysulfuron	Envoke	75%	WDG	2
trifluralin	Treflan HFP, Trifluralin 4 EC, Trifluralin HF, Triflurex HFP, Trust	4 lb a.i./gal	EC	3

[1]The numerical system to describe mechanisms of action is taken from the Weed Science Society of America. Mechanisms of action are as follows:

1 ACCase inhibition
2 ALS inhibition
3 Microtubule assembly inhibition
4 Synthetic auxin
5 Photosystem II, different binding behavior than group 7
7 Photosystem II, different binding behavior than group 5
9 EPSP synthase inhibition
10 Glutamine synthetase inhibition
12 Carotenoid biosynthesis inhibition at PSD
14 PPO inhibition
15 Inhibition of very long-chain fatty acids
17 Unknown mechanism of action
22 Photosystem I electron diversion

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
EARLY PREPLANT BURNDOWN: Emerged annual weeds in no-till, strip-till, or stale seedbed systems	Glyphosate	0.56 to 1.13 lb a.e.	See Table 10-9 for rates of various products. Apply any time prior to planting to control emerged weeds. See Table 10-3 for weed response. Does not adequately control cutleaf eveningprimrose, field pansy, or Carolina geranium; may not adequately control wild radish. Rates for small grain cover crops: Wheat < 12 inches: 0.56 lb a.e. Wheat > 12 inches: 0.75 lb a.e. Rye < 18 inches: 0.56 lb a.e. Rye > 18 inches: 0.75 lb a.e. See comments below for glyphosate-resistant horseweed.
	Glyphosate + 2,4-D (3.8 lb a.e./gal)	0.56 to 1.13 lb a.e. + 0.5 to 2 pt.	See comments for glyphosate alone. Numerous brands of 2,4-D. Many, but not all, brands are labeled for application at least 30 days ahead of cotton planting. No problems with cotton tolerance have been observed in NC research when any formulation of 2,4-D was applied 30 or more days ahead of cotton planting. See Table 10-3 for weed response. Six to 8 fl oz of 2,4-D are adequate for cutleaf eveningprimrose; use 1 pint for most other weeds and 2 pt for horseweed. See later section on glyphosate-resistant horseweed. Glyphosate plus 2,4-D is not adequately effective on Carolina geranium or field pansy. Adjust rates accordingly for formulations other than 3.8 lb a.e./gal. Enlist One can be used for burndown.
	Glyphosate + dicamba (4 L)	0.56 to 1.13 lb a.e. + 8 fl oz	See comments for glyphosate alone. Multiple brands of dicamba, formulated as DMA salt and DGA salt; not all brands registered for preplant application to cotton. Following application of dicamba and a minimum of 1-inch rainfall, a waiting period of at least 21 days is required before planting. It is important that this restriction be followed to avoid cotton injury. This combination suppresses Carolina geranium and curly dock but is somewhat less effective on primrose than glyphosate + 2,4-D. This tank mixture will control glyphosate-resistant horseweed. Adjust rates accordingly for formulations other than 4 lb a.e./gal. Engenia or XtendiMax can be used for burndown
	Glyphosate + 2,4-D + dicamba (Burnmaster 4.07 EC) or (Spitfire 3.57 EC)	0.56 to 1.13 lb a.e. + 1.5 to 2 pt or 1.5 to 2 pt	See comments for glyphosate, glyphosate + 2,4-D, and glyphosate + dicamba. Burnmaster and Spitfire are premixes of 2,4-D plus dicamba. Following application and a minimum of 1-inch rainfall, a waiting period of at least 30 days is required before planting. At the 2-pint rate, Burnmaster or Spitfire will control glyphosate-resistant horseweed.
	Glyphosate + carfentrazone (Aim 2 EC)	0.56 to 1.13 lb a.e. + 0.5 to 1 fl oz	See comments for glyphosate alone. Aim added to glyphosate will increase speed of control and may improve control of some species, but long-term control is generally not improved. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed. There is no waiting period between application and planting.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
EARLY PREPLANT BURNDOWN: Emerged annual weeds in no-till, strip-till, or stale seedbed systems	Glyphosate + flumiclorac (Resource 0.86 EC)	0.56 to 1.13 lb a.e. + 2 to 4 fl oz	See comments for glyphosate alone. Resource added to glyphosate will increase speed of control and may improve control of some species. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed. There is no waiting period between application and planting.
(continued)	Glyphosate + flumioxazin (51 WDG) (4 SC)	0.56 to 1.13 lb a.e. + 1 to 2 oz 1 to 2 fl oz	See comments for glyphosate alone. Multiple brands of flumioxazin; see Table 10-1. Applied at 1 oz/acre, flumioxazin will give 2 to 4 weeks residual control of lambsquarters, pigweed, prickly sida, spurge, and Florida pusley. At 2 oz/acre, flumioxazin will give 6 to 8 weeks residual control of these species. Application to cover crop or dense stand of winter weeds may reduce residual control. Tillage after application will reduce or eliminate residual control. Regardless of glyphosate product used, flumioxazin labels recommend a nonionic surfactant. A minimum of 14 days must pass and a 1-inch rainfall must occur between flumioxazin application and cotton planting when flumioxazin is applied at 1 oz/acre; 21 days must pass when applied at 1.5 to 2 oz/acre. If strip-tillage will follow flumioxazin application, the waiting interval can be reduced to 14 days for the 2 oz. rate. A minimum of 30 days must pass, and 1 inch of rainfall must occur, between flumioxazin application and planting of conventionally tilled cotton. Dicamba or 2,4-D may be added to this mixture. Carefully follow label directions for cleaning out sprayer after each day's use.
	Glyphosate + pyraflufen (ET 0.208 EC)	0.56 to 1.13 lb a.e. + 0.5 to 2 fl oz.	See comments for glyphosate alone. ET added to glyphosate will increase speed of control and may improve control of some species, but long-term control is generally not improved. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed.
	Glyphosate + thifensulfuron + rimsulfuron (LeadOff 33.4 WDG) (Crusher 50 WDG)	0.56 to 1.13 lb a.e. + 1.5 oz 1.0 oz	Thifensulfuron + rimsulfuron is a 1:1 ratio premix product. Apply from late fall to 30 days prior to planting. Controls emerged winter annual weeds plus provides residual control of later emerging winter weeds. See label for adjuvant recommendations. Dicamba or 2,4-D can be included, especially for emerged horseweed, cutleaf eveningprimrose, Carolina geranium, or larger wild radish. Best use of thifensulfuron + rimsulfuron is a late fall or winter application followed by another burndown containing flumioxazin 3 to 4 weeks ahead of planting.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
EARLY PREPLANT BURNDOWN: Emerged annual weeds in no-till, strip-till, or stale seedbed systems (continued)	Glyphosate + thifensulfuron + tribenuron (50 WDG, 1:1 ratio) (50 WDG, 2:1 ratio) (75 WDG, 2:1 ratio)	0.56 to 1.13 lb a.e. + 0.8 oz 0.75 oz 0.5 oz	Thifensulfuron + tribenuron is a premix product. Multiple brands available; see Table 10-1. See comments for glyphosate alone. Add surfactant according to the thifensulfuron + tribenuron label. Thifensulfuron + tribenuron should be applied at least 14 days prior to planting. This tank mix will not control cutleaf eveningprimrose, wild radish, or glyphosate-resistant horseweed. Tank mix more effective on Carolina geranium, curly dock, henbit, swinecress, Virginia pepperweed, wild mustard, and wild radish than glyphosate alone.
	paraquat (2 lb/gal brands) paraquat (3 lb/gal brands)	2.6 to 4 pt 1.7 to 2.7 pt	Multiple brands available; see Table 10-1. Apply any time prior to planting to control emerged weeds. See Table 10-3 for weed response. Add surfactant or crop oil according to label directions. Rates for rye cover crop are 2 pints of 2 lb/gal product or 1.33 pt of 3 lb/gal product. Rates for wheat are 2.5 pt of 2 lb/gal product or 1.67 pt of 3 lb/gal product. Best control of small grain cover crops will be achieved if paraquat applied at the boot stage or later. Usually not adequately effective on cutleaf eveningprimrose, horseweed, or larger wild mustard or wild radish. Tank mixes with diuron are often more effective than paraquat alone.
	glufosinate (2.34 L)	29 to 43 fl oz	Multiple brands; see Table 10-1. Glufosinate can be applied any time prior to cotton emergence. Control is greatly affected by temperature; apply on a sunny day with temperature above 75 degrees. The primary use for glufosinate in burndown would be for glyphosate-resistant horseweed. See below section on *Glyphosate-Resistant Horseweed* and comments in chapter text.
EARLY PREPLANT BURNDOWN: Glyphosate-resistant horseweed	Glyphosate + 2,4-D (3.8 lb a.e./gal) + flumioxazin (51 WDG) (4 SC)	0.56 to 1.13 lb a.e. + 2 pt. + 2 oz 2 fl oz	Assume all horseweed is glyphosate-resistant. Glyphosate plus 2,4-D plus flumioxazin or glyphosate plus dicamba plus flumioxazin are the preferred treatments. See previous comments concerning waiting intervals between application of 2,4-D, dicamba, and flumioxazin and planting. Apply on a warm day using at least 15 GPA. The Sharpen label specifies a 42-day waiting interval between application and cotton planting, plus accumulation of 1 inch of rainfall. Dicamba or 2,4-D may be added to this mixture. Glufosinate is recommended only for fields where growers have failed to control glyphosate-resistant horseweed and it is time to plant cotton. Best results will be obtained if sprayed when daytime temperatures exceed 75 degrees. Glufosinate is not effective in cool weather. A minimum of 15 GPA and fine spray droplets are suggested. Premix products containing dicamba + 2,4-D (Burnmaster and Spitfire) may be used at 2 pt instead of dicamba or 2,4-D alone.
	Glyphosate + dicamba (4 L) + flumioxazin (51 WDG) (4 SC)	0.56 to 1.13 lb a.e. + 8 fl oz + 2 oz 2 fl oz	
	Glyphosate + saflufenacil (Sharpen 2.85 F)	0.56 to 1.13 lb a.e. + 1 fl oz	
	glufosinate (2.34 L)	29 to 43 fl oz	

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
AT PLANTING BURNDOWN: Burndown of cover crops and weeds at planting	Glyphosate	0.56 to 1.13 lb a.e.	Multiple brands of glyphosate, paraquat, and glufosinate; see Tables 10-1 and 10-9. If an early burndown treatment was applied, apply glyphosate or paraquat in combination with desired residual herbicides at planting. If an early burndown treatment was not used, apply glyphosate or paraquat 7 to 21 days ahead of planting. If weeds are emerged at planting, make a second application in combination with desired residual herbicides. Glyphosate and paraquat rates depend upon weed species and size; see labels for details. Add surfactant or crop oil to paraquat according to label directions. Need for adjuvants with glyphosate depends upon brand used; see specific labels for details. For glufosinate, see comments under early preplant burndown. Glufosinate will not adequately control cover crops. Glyphosate rates for small grain cover crops: Wheat < 12 inches: 0.56 lb a.e. Wheat > 12 inches: 0.75 lb a.e. Rye < 18 inches: 0.56 lb a.e. Rye > 18 inches: 0.75 lb a.e. Paraquat rates for small grain cover crops: Wheat: 2.6 pt of 2 lb/gal product or 1.7 pt of 3 lb/gal product Rye: 2.0 pt of 2 lb/gal product or 1.33 pt of 3 lb/gal product
	paraquat (2 lb/gal brands) (3 lb/gal brands)	2.6 to 4 pt 1.7 to 2.7 pt	
	glufosinate (2.34 L)	29 to 43 fl oz	
PREPLANT INCORPORATED, ANY VARIETY: annual grasses and small-seeded broadleaf weeds	pendimethalin (3.3 EC) pendimethalin (3.8 L)	1.2 to 3.6 pt 2 to 4 pt	Multiple brands; see Table 10-1. Incorporate in top 2 in. of final seedbed according to label directions. Deep incorporation, especially on sandy soils, may cause stunting and delayed crop development. Incorporation of trifluralin and pendimethalin can be delayed 24 hours and 7 days, respectively. Immediate incorporation suggested. See Tables 10-4 and 10-5 for weeds controlled. See labels for specific rates on various soils. Not effective on organic soils.
	trifluralin (4 EC)	1 to 2 pt	
PREEMERGENCE, ANY VARIETY: annual broadleaf weeds	diuron (4 F) diuron (80 DF)	1 to 2 pt 0.63 to 1.25 lb	Multiple brands; see Table 10-1. See labels for specific rates on various soils. Not effective on organic soils. Apply before crop emergence. May be mixed with Warrant, fomesafen, pendimethalin, or pyrithiobac. See rotational restrictions on labels.
	fluometuron (Cotoran 4 F)	1 to 2 qt	See label for specific rates on various soils. Not effective on organic soils. Apply before crop emergence. May be mixed with Warrant, fomesafen, pendimethalin, or pyrithiobac.
	fluridone (Brake 1.2F)	1 to 2 pt	Suggested primarily for Palmer amaranth control. May be tank-mixed with any other herbicide registered for preemergence application to cotton. Brake label requires a mixture if Brake is used at less than 21 oz/acre. Not effective on organic soils. See label for rotational restrictions.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
PREEMERGENCE, ANY VARIETY: annual broadleaf weeds (continued)	fluridone + fomesafen (Brake F16 2.7 F)	1 pt	Suggested primarily for Palmer amaranth control. Limited effectiveness on organic soils. At 1 pt, Brake F16 is equivalent to 1 pt of Brake plus 12 oz of Reflex. See label for rotational restrictions.
	fomesafen (1.88 L) fomesafen (2.0 L) fomesafen (2.87 L)	1.06 pt 1 pt 0.7 pt	Multiple brands; see Table 10-1. Labels restrict application only to coarse-textured soils. There is a greater chance of injury on medium- or fine-textured soils. Suggested primarily for control of Palmer amaranth. May be mixed with Warrant, diuron, Cotoran, pendimethalin, or pyrithiobac. Fomesafen applied to very dry soil followed by rainfall or irrigation shortly after planting can cause cotton injury. Injury may also be observed if the first rainfall after application splashes soil onto emerging cotton seedlings. Reducing fomesafen rates to 10 to 12 oz when mixed with Warrant, diuron, or Cotoran may reduce injury with little reduction in Palmer amaranth control.
	pyrithiobac (3.2 L)	1.7 to 2.1 fl oz	Multiple brands; see Table 10-1. Do not apply to soils with less than 0.5% organic matter. May be mixed with diuron, Cotoran, fomesafen, or pendimethalin. Palmer amaranth biotypes resistant to pyrithiobac are common in North Carolina.
PREEMERGENCE, ANY VARIETY: annual grasses and various broadleaf weeds	acetochlor + fomesafen (Warrant Ultra 3.45 CS)	3 pt	At 3 pt, this premix is equivalent to 2.8 pt (1.06 lb a.i.) of Warrant plus 15 fl oz (0.24 lb a.i.) of Reflex. See comments for Warrant alone and fomesafen alone. Maximum seasonal rates for Warrant and fomesafen are 3 lb a.i. and 0.34 lb a.i., respectively. Label allows preemergence application only to sandy loam, loamy sand, or sandy clay loam soils. Can add diuron..
	acetochlor (Warrant 3 CS) + diuron (4 F) diuron (80 DF)	3 pt + 1 to 2 pt 0.63 to 1.25 lb	See above comments for Warrant, diuron, Cotoran, and fomesafen applied alone.
	acetochlor (Warrant 3 CS) + fluometuron (Cotoran 4 F)	3 pt + 1 to 2 qt	
	acetochlor (Warrant 3 CS) + fomesafen (1.88 L) fomesafen (2.0 L) fomesafen (2.87 L)	3 pt + 1.06 pt 1 pt 0.7 pt	

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
PREEMERGENCE, ANY VARIETY: annual grasses and various broadleaf weeds (continued)	acetochlor (Warrant 3 CS) + fomesafen + diuron (4F)	2 pt + 10 fl oz + 1 pt	This three-way combination with reduced rates of Warrant and fomesafen has performed well on Palmer amaranth with less potential for crop injury than two-way mixes at full rates.
	diuron (4 F) diuron (80 DF) + fomesafen (1.88 L) fomesafen (2.0 L) fomesafen (2.87 L)	1 to 2 pt 0.63 to 1.25 lb + 1.06 pt 1 pt 0.7 pt	See above comments for diuron and fomesafen applied alone. On most soils, the suggested rate of diuron is 1 pt or 0.63 lb.
PREEMERGENCE, ANY VARIETY: annual grasses, pigweed, and lambsquarters	pendimethalin (3.3 EC) pendimethalin (3.8 L)	 2.4 to 3.6 pt 2.1 to 4 pt	Multiple brands; see Table 10-1. Pendimethalin is more effective when incorporated. If applied preemergence, a tank mix with another herbicide is suggested. See labels for specific rates on various soils. Not effective on organic soils.
PREEMERGENCE, ANY VARIETY: annual grasses and pigweed	acetochlor (Warrant 3 CS)	3 pt	Warrant is usually applied in combination with another preemergence herbicide such as diuron, Cotoran, or fomesafen. Warrant is effective on mineral-organic soils; see label for rates.
POSTEMERGENCE OVERTOP, ANY VARIETY: annual grasses	clethodim (2 EC) clethodim (0.97 EC)	6 to 8 fl oz 9 to 16 fl oz	Multiple brands; see Table 10-1. See labels for maximum weed size to treat, suggested rates for specific species, and adjuvant recommendations.
	fluazifop (Fusilade DX 2 EC)	8 to 12 fl oz	
	quizalofop (0.88 EC)	7 to 8 fl oz	
	sethoxydim (1.5 EC) sethoxydim (2 EC)	16 fl oz 24 fl oz	
POSTEMERGENCE OVERTOP, ANY VARIETY: rhizome johnsongrass	clethodim (2 EC) clethodim (0.97 EC)	8 to 16 fl oz 12 to 32 fl oz	Multiple brands. Apply to actively growing johnsongrass 24 in. tall or less. Repeat if needed when regrowth or new plants are 6 to 12 in. tall. See labels for rates for the second application and for adjuvant recommendations.
	fluazifop (Fusilade DX 2 EC)	12 fl oz	
	quizalofop (0.88 EC)	10 fl oz	
	sethoxydim (1.5 EC) sethoxydim (1 EC)	24 fl oz 36 fl oz	
POSTEMERGENCE OVERTOP, ANY VARIETY: bermudagrass	clethodim (2 EC) clethodim (0.97 EC)	8 to 16 fl oz 12 to 32 fl oz	Multiple brands; see Table 10-1. Apply to actively growing bermudagrass before runners exceed 6 in. A second application may be made if needed when regrowth is 6 in. or less. See labels for rates for the second application and for adjuvant recommendations. Spray coverage, especially with second application, may be improved by directing spray under cotton.
	fluazifop (Fusilade DX 2 EC)	12 fl oz	
	quizalofop (0.88 EC)	10 fl oz	
	sethoxydim (1.5 EC) sethoxydim (1 EC)	24 fl oz 36 fl oz	

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE OVERTOP, ANY VARIETY: annual broadleaf weeds	pyrithiobac (3.2 SL)	2.6 to 3.8 fl oz	Multiple brands; see Table 10-1. Apply from cotyledonary stage of cotton until 60 days before harvest. Can apply twice per season, but do not exceed 5.1 fl oz per season. Avoid application during or near a period of cool weather or to thrips-infested cotton. Add nonionic surfactant at 1 qt per 100 gal spray solution. See label for weeds controlled and recommended weed size to treat. See label for precautions on mixing with insecticides or other herbicides. Will not control ALS-resistant Palmer amaranth.
	trifloxysulfuron (Envoke 75 WDG)	0.1 oz	Apply after cotton has a minimum of five true leaves (seven preferred) until 60 days prior to harvest. May be applied twice, but do not exceed 0.0188 pound active ingredient trifloxysulfuron per acre per year from combined use of all products containing trifloxysulfuron. Add nonionic surfactant at 1 qt per 100 gal; do not use other types of adjuvants. Do not mix with postemergence grass control herbicides. See label for precautions on mixing with insecticides and for weeds controlled and weed size to treat. May be applied overtop at 0.15 oz per acre if needed for larger weeds. Will not control ALS-resistant Palmer amaranth.
	pyrithiobac (3.2 L) + trifloxysulfuron (Envoke 75 WDG)	1.3 to 1.9 fl oz + 0.1 oz	See comments for pyrithiobac and Envoke applied alone. Cotton should be in at least the fifth leaf stage, preferably larger, for this application. Compared to Evoke alone, mixture is more effective on eclipta, jimsonweed, and spurred anoda. Compared to pyrithiobac alone, mixture is more effective on ragweed, lambsquarters, tall morningglory, sicklepod, and nutsedge.
POSTEMERGENCE OVERTOP, **GLUFOSINATE-TOLERANT VARIETIES**: annual grasses and broadleaf weeds	glufosinate (2.34 L)	29 to 43 fl oz	Multiple brands; see Table 10-1. Apply anytime up to the early bloom stage of cotton. Multiple applications are allowed, but do not exceed a total of 87 fl oz if 29 fl oz are applied per application or 72 fl oz if the first application is greater than 29 fl oz. For Palmer amaranth larger than 3 inches, apply 43 oz followed 10 days later by 29 oz. See label for suggested spray volume, pressure, and nozzle selection. See label for weeds controlled, recommended weed size for treatment, application directions and rates, and precautions. Application rate and timing of application are critical. In general, broadleaf weeds should be 4 in. or less. Pigweed species and annual grasses should be 3 in. or less. Surfactant or crop oil is not needed; ammonium sulfate may improve control. Do not apply glufosinate sooner than 2 hours after sunrise nor later than 1 hour before sunset. See comments in text concerning use of glufosinate on WideStrike varieties.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE OVERTOP, **GLUFOSINATE-TOLERANT VARIETIES**: annual grasses and broadleaf weeds (continued)	glufosinate (2.34 L) + S-metolachlor (7.62 EC)	29 to 43 fl oz + 1 to 1.33 pt	See comments for glufosinate alone. See Table 10-1 for S-metolachlor brands. Apply overtop to cotton at least 3 in. tall. Do not add any adjuvants. Do not tank mix pyrithiobac with glufosinate plus S-metolachlor. Some foliar burn from S-metolachlor may occur; tank mixing with insecticides may increase crop response. S-metolachlor provides residual control of annual grasses and pigweed species.
	glufosinate (2.34 L) + pyrithiobac (3.2 L)	29 to 43 fl oz + 1.3 to 2.7 fl oz	See comments for glufosinate alone and pyrithiobac alone. Compared to glufosinate alone, tank mix will improve control of larger pigweed, including Palmer amaranth (unless it is ALS resistant), and will provide residual control of pigweed, lambsquarters, prickly sida, jimsonweed, smartweed, spurred anoda, and velvetleaf. Use 2.7 oz of pyrithiobac to suppress or control spreading dayflower. Apply overtop from cotyledonary stage to early bloom stage. Adjuvants are not necessary. Tank mixing with insecticides may increase crop injury.
POSTEMERGENCE OVERTOP, **GLYPHOSATE-TOLERANT VARIETIES**: annual and perennial grasses, annual broadleaf weeds, and nutsedge; suppression of perennial broadleaf weeds	glyphosate	0.75 to 1.13 lb a.e.	See Table 10-8 for rate conversions among formulations. Glyphosate may be applied overtop or directed any time from cotton emergence to 7 days prior to harvest. See labels for maximum use rates per season. Clethodim, Fusilade DX, quizalofop, or sethoxydim may be mixed with glyphosate to control volunteer Roundup Ready corn. See the discussion on *Herbicide Resistance Management* in the text of this chapter.
	glyphosate + acetochlor (Warrant 3 ME)	0.75 to 1.13 lb a.e. + 3 pt	See comments for glyphosate alone. Warrant will not control emerged weeds, but it will provide residual control of annual grasses and pigweed species. Tank mix may be applied overtop cotton that is completely emerged until the first bloom stage. Some foliar burn may occur. Foliar burn may be worse under high temperature or high humidity or when dew is present at application. Insecticides in the mixture often increase burn.
	glyphosate + dimethenamid-P (Outlook 6EC)	0.75 to 1.13 lb a.e. + 12-16 fl oz	See comments for glyphosate applied alone. Can apply from first true leaf to midbloom stage. Outlook will not control emerged weeds, but it will provide residual control of annual grasses and pigweed species. Optimum timing is 2- to 3-leaf cotton, and before weeds emerge. Make only one application per year. Some foliar burn may occur. Foliar burn may be worse under high temperature or high humidity or when dew is present at application. Insecticides in the mixture often increase burn. Suggested rates are 12 oz on coarse soils, 14 oz on medium soils, and 16 oz on fine soils.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE OVERTOP, **GLYPHOSATE-TOLERANT VARIETIES**: annual and perennial grasses, annual broadleaf weeds, and nutsedge; suppression of perennial broadleaf weeds (continued)	glyphosate + S-metolachlor (7.62 EC)	0.75 to 1.13 lb a.e. + 1 to 1.33 pt	Multiple brands; see Table 10-1. See comments for glyphosate alone. Tank mix may be applied overtop from 3 in. tall until 100 days before harvest. Do not mix pyrithiobac with glyphosate plus S-metolachlor. Some foliar burn may occur. Foliar burn may be worse under high temperature or high humidity or when dew is present at application. Insecticides in the mixture often increase burn.
	glyphosate + S-metolachlor (Sequence 5.25 EC)	2.5 to 3.5 pt	Premix contains 2.25 lb a.e. glyphosate plus 3 lb/gal S-metolachlor. Apply 2.5 pt on cotton with less than 5 leaves. Can increase rate to 3.5 pt on cotton with 5 to 10 leaves. Do not apply beyond the 10-leaf stage. Do not include AMS or other adjuvants.
	glyphosate + pyrithiobac (3.2 L)	0.75 to 1.13 lb a.e. + 1.3 to 3.8 fl oz t	Multiple brands. See comments for glyphosate and pyrithiobac applied alone. Tank mix may be applied overtop from the cotyledonary stage until 60 days prior to harvest.
	glyphosate + trifloxysulfuron (Envoke 75 WDG)	0.75 to 1.13 lb a.e. + 0.1 oz	See comments for glyphosate and Evoke applied alone. Tank mix can be applied overtop cotton from 5-leaf stage until 60 days prior to harvest. For better crop safety, however, cotton should have at least 7 to 8 leaves at time of application.
POSTEMERGENCE OVERTOP, **XTENDFLEX VARIETIES**: annual and perennial grasses, annual broadleaf weeds, and nutsedge; suppression of perennial broadleaf weeds	glyphosate + dicamba (Engenia 5S)	0.75 to 1.13 lb a.e. + 12.8 fl oz	See section in text on *Weed Management in Roundup Ready XtendFlex Cotton*. These treatments can be applied from cotton emergence until 7 days before harvest; it is suggested to not apply after cotton is 12 to 16 inches tall. Apply to weeds less than 4 inches. Do not add AMS. See the websites mentioned in *Weed Management in Roundup Ready XtendFlex Cotton* for permissible tank mixes and adjuvants. Drift to susceptible crops is a significant risk. It is not permissible to mix other herbicides or insecticides with Engenia or XtendiMax.
	glyphosate + dicamba (XtendiMax 2.9S)	0.75 to 1.13 lb a.e. + 22 fl oz	
POSTEMERGENCE OVERTOP, **ENLIST VARIETIES:** annual and perennial grasses, annual broadleaf weeds, and nutsedge; suppression of perennial broadleaf weeds	glyphosate + 2,4-D (Enlist One 3.8S)	0.75 to 1.13 lb a.e. + 2 pt	See section in text on *Weed Management in Enlist Cotton*. These treatments can be applied from cotton emergence to midbloom stage. Apply to weeds 3 to 6 inches tall; Palmer amaranth should be less than 4 inches. See the website mentioned in *Weed Management in Enlist Cotton* for permissible tank mixes and adjuvants. Drift to susceptible crops is a significant risk. No tank mixes are allowed with Enlist Duo. Dual Magnum, Warrant, and selected insecticides can be mixed with Enlist One.
	glyphosate + 2,4-D (Enlist Duo 3.3S)	4.75 pt	
POSTEMERGENCE-DIRECTED, **ANY VARIETY**: annual broadleaf weeds, small annual grasses, and nutsedge	MSMA (6 lb/gal) (6.6 lb/gal)	 2.67 pt 2.4 pt	Multiple brands. Do not apply after first bloom. Do not apply these rates overtop. Primarily controls cocklebur and nutsedge. Two applications usually needed for acceptable nutsedge control.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, **ANY VARIETY:** annual broadleaf weeds, small annual grasses, and nutsedge (continued)	diuron (4 F) + MSMA (6 lb/gal) (6.6 lb/gal)	1.6 to 2.4 pt + 2.67 pt 2.4 pt	Multiple brands; see Table 10-1. Direct to cotton at least 12 in. tall. See label and adjust rate according to soil types. Add nonionic surfactant at 1 to 2 qt per 100 gal spray solution. Label prohibits use on sand or loamy sand soils, or any soil with less than 1% organic matter, although research in NC has not shown this to be a problem. See rotational restrictions on diuron label. Do not apply MSMA after first bloom. Aim at 1 fl oz or Cobra at 6 to 8 fl oz may be added to this combination to improve control of larger morningglory. Cotton should be at least 16 in. tall when applying Aim. Do not allow Aim to contact green stem tissue.
	flumioxazin (51 WDG) (4 SC) + MSMA (6 lb/gal) (6.6 lb/gal)	 2 oz 2 fl oz + 2.67 pt 2.4 pt	Multiple brands; see Table 10-1. Direct to cotton at least 16 in. tall. Direct spray to lower 2 in. of cotton stem. Do not allow spray to contact green stem tissue. Add nonionic surfactant at 1 qt per 100 gal spray solution. Do NOT use crop oil concentrate, methylated seed oil, organo-silicone adjuvants, or any adjuvant product containing any of these. Do not apply MSMA after first bloom. No rotational restrictions of concern.
	flumioxazin + pyroxasulfone (Fierce 76 WDG) + MSMA (6 lb/gal) (6.6 lb/gal)	3 oz + 2.67 pt 2.4 pt	Same use pattern as flumioxazin; see above comments. Pyroxasulfone gives good residual control of grasses and small-seeded broadleaf weeds, including Palmer amaranth.
	fluometuron (Cotoran 4 F) + MSMA (6 lb/gal) (6.6 lb/gal)	 1 to 2 qt + 2.67 pt 2.4 pt	Direct Cotoran to cotton at least 3 in. tall. Do not apply MSMA after first bloom. Add nonionic surfactant at 1 qt per 100 gal. See rotational restrictions on Cotoran label. S-metolachlor at 1 to 1.3 pt may be added for additional residual control of annual grasses, pigweed species, and doveweed.
	lactofen (Cobra2 EC) + MSMA (6 lb/gal) (6.66 lb/gal)	12.5 fl oz + 2.67 pt 2.4 pt	Direct Cobra to cotton at least 6 to 8 in. tall, preferably larger. Add 1 qt nonionic surfactant per 100 gal spray solution for cotton less than 12 in.; add 0.5 to 1 pt per acre crop oil concentrate on cotton larger than 12 in. Do not apply MSMA after first bloom. This combination does not provide residual control.
	lactofen (Cobra 2 EC) + diuron (4 F) + MSMA(6 lb/gal) (6.6 lb/gal)	6 to 12.5 fl oz + 0.8 to 1.2 pt + 2.67 pt 2.4 pt	Direct to cotton at least 12 in. tall. Add 1 to 2 pt per acre of crop oil concentrate. Do not apply MSMA after first bloom. See rotational restrictions on diuron label.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, **ANY VARIETY:** annual broadleaf weeds, small annual grasses, and nutsedge (continued)	prometryn (4 F) + MSMA (6 lb/gal) (6.6 lb/gal)	1.3 to 2.84 pt + 2.67 pt 2.4 pt	Multiple brands; see Table 10-1. Direct 1.3 pt prometryn after cotton is at least 6 in. tall; increase rate to 2.4 pt after cotton is at least 12 in. tall. At the higher rate, prometryn may give limited residual control of susceptible broadleaf weeds, such as pigweed. Add nonionic surfactant at 2 qt per 100 gal. Do not apply MSMA after first bloom. See rotational restrictions on prometryn label. Aim at 1 fl oz or Cobra at 6 to 8 fl oz may be added to this combination to improve control of large morningglory. Cotton should be at least 16 in. tall when applying Aim. Do not allow Aim to contact green stem tissue. S-metolachlor at 1 to 1.3 pt can be included for additional residual control of annual grasses, pigweed species, and doveweed.
	prometryn + trifloxysulfuron (Suprend 80WDG) + MSMA (6 lb/gal) (6.6 lb/gal)	 1.25 lb + 2.67 pt 2.4 pt	Direct to cotton at least 6 to 8 inches tall. Add nonionic surfactant at 1 qt per 100 gal. Do not apply MSMA after first bloom. See rotational restrictions on Suprend label.
POSTEMERGENCE-DIRECTED, **GLYPHOSATE-TOLERANT VARIETIES**: annual grass and broadleaf weeds, nutsedge, and suppression of perennial weeds	glyphosate	0.75 to 1.13 lb a.e.	Can be directed at any growth stage. Precise directing to avoid contact with the crop is not necessary. Precision, however, is required when directing tank mixes. Use of other herbicides, in addition to glyphosate, is recommended to aid in resistance management. See the discussion on *Herbicide Resistance Management* in the text of this chapter. See Table 10-9 for conversions among glyphosate formulations.
	glyphosate + acetochlor (Warrant 3.0 ME)	0.75 to 1.13 lb a.e. + 3 pt	Can be directed to cotton up to first bloom stage. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will not improve control of emerged weeds, but it can give residual control of grasses and pigweed species.
	glyphosate + acetochlor + fomesafen (Warrant Ultra 3.45 CS)	0.75 to 1.13 + 3 pt	Use as a layby application to cotton with a minimum of 4 inches of bark on the stem. Avoid contact with cotton foliage. Do not use Warrant Ultra at layby if Warrant Ultra or fomesafen was used preemergence. Do not exceed a maximum of 3 lb active acetochlor per year from all applications.
	glyphosate + carfentrazone (Aim 2 EC)	0.75 to 1.13 lb a.e. + 1 to 1.5 fl oz	Direct to cotton at least 16 in. tall; do not allow Aim to contact green stem tissue. Add crop oil concentrate according to Aim label. Compared to glyphosate alone, this combination improves control of larger morningglory. This tank mix does not give residual control.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, **GLYPHOSATE-TOLERANT VARIETIES**: annual grass and broadleaf weeds, nutsedge, and suppression of perennial weeds (continued)	glyphosate + dimethenamid-P (Outlook 6EC)	0.75 to 1.13 lb a.e. + 12 to 16 fl oz	Can be directed to cotton up to midbloom. See comments for glyphosate applied alone. Outlook does not improve control of emerged weeds, but it can give residual control of annual grasses and pigweed species. Suggested rates are 12 oz on coarse soils, 14 oz on medium soils, and 16 oz on fine soils.
	glyphosate + diuron (4 F)	0.75 to 1.13 lb a.e. + 1 to 1.5 pt	Multiple brands; see Table 10-1. Direct to cotton at least 8 in. tall. Use 1 pt diuron on cotton 8 to 12 in. tall; rate can be increased to 1.5 pt on cotton at least 12 in. tall. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will improve control of larger morningglory and may provide residual control of small-seeded broadleaf weeds, such as pigweed. This tank mix may give less control of larger grasses or grasses under drought stress compared with glyphosate alone.
	glyphosate + flumioxazin (51 WDG) (4 SC)	0.75 to 1.13 lb a.e. + 1 to 2 oz 1 to 2 fl oz	Multiple brands; see Table 10-1. Direct to lower 2 in. or less of stem on cotton at least 16 in. tall. Do not allow spray to contact green stem tissue. Add nonionic surfactant at 1 qt per 100 gal spray solution. Do NOT use crop oil concentrate, methylated seed oil, organo-silicone adjuvants, or any adjuvant product containing any of these. Compared to glyphosate alone, this combination will improve control of larger morningglory and provide residual control of several broadleaf weeds.
	glyphosate + flumioxazin + pyroxasulfone (Fierce 76 WDG)	0.75 to 1.13 lb a.e. + 3 oz	Same use pattern as flumioxazin; see above comments. Pyroxasulfone gives good residual control of grasses and small-seeded broadleaf weeds, including Palmer amaranth.
	glyphosate + S-metolachlor (7.62 EC)	0.75 to 1.13 lb a.e. + 1 to 1.33 pt	Multiple brands; see Table 10-1. Direct to cotton 3 in. tall through layby. Add surfactant according to the label of the brand of glyphosate used. See above comments for glyphosate alone. Compared to glyphosate alone, this combination will not improve control of emerged weeds, but it can give residual control of grasses and pigweed species. Sequence is a premix of glyphosate and S-metolachlor. It can be directed at 2.5 pints per acre.
	glyphosate + prometryn (4 F)	0.75 to 1.13 lb a.e. + 1 to 2 pt	Multiple brands; see Table 10-1. Direct to cotton at least 6 to 8 in. tall. Use 1 to 1.3 pt prometryn on cotton 6 to 12 in. tall; rate can be increased to 2.4 pt on cotton at least 12 in. tall. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will improve control of larger morningglory and may provide residual control of small-seeded broadleaf weeds, such as pigweed. This tank mix may give less control of larger grasses or grasses under drought stress compared with glyphosate alone.

continued

Table 10-2. Herbicide Information for Cotton; see Table 10-1 for brand names (continued)

Application Method and Target Weeds	Herbicide Common Name	Broadcast Rate per Acre	Comments
POSTEMERGENCE-DIRECTED, **GLYPHOSATE-TOLERANT VARIETIES**: annual grass and broadleaf weeds, nutsedge, and suppression of perennial weeds (continued)	glyphosate + prometryn + trifloxysulfuron (Suprend 80 WDG)	0.75 to 1.13 lb a.e. + 1.25 lb	Direct to cotton at least 6 to 8 in. tall. Add surfactant according to the label of the brand of glyphosate used. Compared to glyphosate alone, this combination will improve control of larger morningglory and nutsedge and provide residual control of small-seeded broadleaf weeds, such as pigweed. This tank mix may give less control of larger grasses or grasses under drought stress compared with glyphosate alone.
	glyphosate + pyroxasulfone (Zidua 85 WDG)	0.75 to 1.13 lb a.e. + 0.75 to 2.1 oz	Zidua is similar to Warrant, S-metolachlor, and Outlook. The tank mix can directed to cotton from five leaves to first bloom. Zidua provides residual control of grasses and small-seeded broadleaf weeds, including Palmer amaranth. Label prohibits application to coarse-textured soils.
	glyphosate + trifloxysulfuron (Envoke 75 WDG)	0.75 to 1.13 lb a.e. + 0.1 to 0.2 oz	Direct to cotton at least 6 in. tall, preferably taller. Add surfactant according to the Evoke label. Compared to glyphosate alone, this combination will improve control of larger morningglory and nutsedge.
POSTEMERGENCE WITH HOODED SPRAYER, **ANY VARIETY**: annual grass and broadleaf weeds, perennial grass and broadleaf weeds, and nutsedge	glyphosate	0.75 to 1.13 lb a.e.	Rate depends on weed species and size: see label of brand used for specific rates. Hoods should be kept as close to the ground as possible so spray solution does not contact crop. Application to base of non-glyphosate-tolerant cotton will cause injury. Speed should not exceed 5 mph. Use 5 to 10 GPA and maximum pressure of 25 PSI. Do not use liquid nitrogen as the carrier. Other herbicides as discussed in the section on directed applications may be mixed with glyphosate to improve burndown on morningglory and other problem weeds and to provide residual control.
POSTEMERGENCE WITH HOODED SPRAYER, **ANY VARIETY**: annual grass and broadleaf weeds, suppression of nutsedge	paraquat (2 lb/gal brands) (3 lb/gal brands)	 1.2 to 2.4 pt 0.8 to 1.6 pt	Multiple brands; see Table 10-1. Hoods should be kept as close to the ground as possible. Do NOT allow the spray solution to contact cotton plants. Apply in a minimum of 10 GPA (higher GPA preferred) at maximum pressure of 25 PSI. Do not exceed 5 mph. It is suggested cotton be at least 6 in. tall. Add nonionic surfactant according to label. Diuron or prometryn may be mixed with paraquat. Tank mixes are usually more effective than paraquat alone.
	glufosinate (2.34 L)	29 to 43 fl oz	Multiple brands; see Table 10-1. On non-glufosinate-tolerant varieties, keep hoods close to the ground and avoid contact with the cotton. Apply in at least 15 GPA. No adjuvant necessary. Can add diuron, Cotoran, pendimethalin, prometryn, pyrithiobac, or S-metolachlor for residual control.
HARVEST AID: annual grasses and broadleaf weeds	paraquat (2 lb/gal brands) (3 lb/gal brands)	 1 to 2 pt 0.67 to 1.33 pt	Multiple brands; see Table 10-1. Defoliate cotton as normal. After at least 75% to 80% of the bolls are open, the remaining bolls expected to be harvested are mature, and most of the cotton leaves have dropped, apply paraquat in a minimum of 20 gal per acre and add 1 pt nonionic surfactant per 100 gal. Wait 5 days before picking, then pick as soon as possible.

Table 10-3. Weed Response to Burndown Herbicides for Conservation-Tillage Cotton[1]

Weed	2,4-D[2]	glyphosate	glyphosate + dicamba[3]	glyphosate + 2,4-D[2]	glyphosate + flumioxazin[4] + dicamba[3]	glyphosate + flumioxazin[4] + 2,4-D[2]	glyphosate + Leadoff or Crusher[5]	glyphosate + thifensulfuron + tribenuron[6]	glyphosate + Sharpen[7]	paraquat	paraquat + diuron
Annual bluegrass	N	E	E	E	E	E	E	E	E	GE	E
Little barley	N	E	E	E	E	E	E	E	E	G	E
Buttercups	G	E	E	E	E	E	E	E	E	E	E
Carolina geranium	PF	PF	G	F	G	F	G	GE	ND	GE	E
Chickweed	P	E	E	E	E	E	E	E	E	E	E
Cudweed	NP	E	E	E	E	E	E	E	E	FG	G
Curly dock	F	F	GE	FG	F	FG	F	E	ND	NP	P
Cutleaf eveningprimrose	E	PF	G	E	FG	E	PF	F	ND	F[8]	G[8]
Field pansy	P	F	F	F	F	F	ND	F	ND	G	GE
Henbit	PF	G	E	E	E	E	E	E	ND	E	E
Horseweed (marestail)											
glyphosate-susceptible	GE[9]	GE	E	E	E	E	GE	GE	E	PF	G
glyphosate-resistant	GE[9]	N	E	E[9]	E	E[9]	P	P	E	PF	G
Prickly lettuce	G	E	E	E	E	E	E	E	E	P	PF
Ryegrass	N	G	G	G	G	G	GE	G	G	F	FG
Speedwell	PF	E	E	E	E	E	E	E	E	E	E
Swinecress	F	FG	FG	G	ND	E	E	E	E	E	E
Vetch	E	F	E	E	FG	E	ND	G	ND	PF	F
Virginia pepperweed	GE	G	GE	E	GE	E	G	G	ND	G	G
Wheat or rye cover crop [10]	N	E	E	E	E	E	E	E	E	G[12]	GE[12]
Wild mustard, wild radish	FG[11]	FG	G	E	G	E	FG	GE	ND	FG	G

Note: E = excellent, 90% or better control; G = good, 80 to 90% control; F = fair, 50 to 80% control; P = poor, 25 to 50% control; N = no control, less than 25% control; ND = no data.

[1] See Table 10-1 for brand names and Table 10-2 for application rates.
[2] Apply 2,4-D at least 30 days ahead of planting. No waiting period is needed on Enlist cotton.
[3] Following application of dicamba and a minimum of 1 in. of rainfall, a minimum 21-day waiting period is required before planting. No waiting period is needed on XtendFlex cotton.
[4] A minimum of 14 days must pass and 1 inch of rainfall must occur between application of flumioxazin at 1 oz and planting. Delay planting 21 days after application of 1.5 to 2 oz of flumioxazin. See exceptions for strip-tillage in Table 10-2.
[5] Apply Leadoff or Crusher from late fall to 30 days prior to planting. May include 2,4-D or dicamba. See Table 10-1 for brands.
[6] Apply thifensulfuron + tribenuron at least 14 days ahead of planting.
[7] A minimum of 42 days must pass and 1 inch of rainfall must occur between application of Sharpen and cotton planting.
[8] This level of control requires that the primrose be blooming when treated.
[9] This level of control requires 2 pt of 2,4-D.
[10] Glyphosate rate is 0.56 lb a.e. for wheat less than 12 in. or rye less than 18 in., or 0.75 lb a.e. for wheat greater than 12 in. or rye greater than 18 in.
[11] Wild radish and wild mustard control by 2,4-D is good if application is made before plants begin flowering. Use 1 pt per acre of 2,4-D to control these species.
[12] Wheat or rye must have visible seed heads for this level of control.

Table 10-4. Grass and Nutsedge Response to Soil-Applied Herbicides[1]

Weed	pendimethalin or trifluralin PPI	Warrant PRE	diuron PRE	Cotoran PRE	fomesafen PRE	Brake F16 PRE	pendimethalin PRE	pyrithiobac PRE
Bermudagrass	N	N	N	N	N	N	N	N
Broadleaf signalgrass	G	G	P	P	FG	FG	F	P
Crabgrass	E	E	FG	FG	FG	FG	G	P
Crowfootgrass	E	E	FG	FG	ND	ND	G	P
Fall panicum	G	E	P	F	ND	ND	F	PF
Foxtails	E	E	ND	FG	ND	ND	G	P
Goosegrass	E	E	F	F	ND	ND	G	PF
Johnsongrass								
Seedling	E	F	P	P	ND	ND	G	FG
Rhizome	P	N	N	N	N	N	N	N
Texas panicum	G	P	P	P	F	F	F	N
Nutsedge								
Purple	N	N	N	N	PF	F	N	F
Yellow	N	PF	N	N	GE	GE	N	F

Note: PPI = preplant-incorporated; PRE = preemergence

E = excellent, 90% or better control
G = good, 80 to 90% control
F = fair, 50 to 80% control
P = poor, 25 to 50% control
N = no control, less than 25% control
ND = no data

[1] See Table 10-1 for brand names and Table 10-2 for application rates.

Table 10-5. Annual Broadleaf Weed Response to Soil-Applied Herbicides[1]

Weed	pendimethalin or trifluralin PPI	Brake F16 PRE	Cotoran PRE	diuron PRE	fomesafen PRE	pendimethalin PRE	pyrithiobac PRE	Warrant PRE
Cocklebur	N	G	FG	F	G	N	NP	N
Common purslane	E	G	E	E	G	G	G	G
Common ragweed								
glyphosate-susceptible	N	G	E	G	G	N	NP	P
glyphosate-resistant	N	G	E	G	G	N	NP	P
Cowpea	N	ND	P	P	ND	N	FG	N
Crotalaria	N	ND	G	G	ND	N	ND	N
Eclipta	P	GE	G	G	GE	P	ND	FG
Florida beggarweed	P	ND	GE	G	P	N	G	P
Florida pusley	E	ND	FG	PF	P	FG	F	E
Hemp sesbania	N	ND	P	P	P	N	P	N
Jimsonweed	N	ND	G	G	ND	N	FG	N
Lambsquarters	GE	E	E	E	E	G	G	P
Morningglory species								
Tall	P	F	G	F	PF	P	P	P
Other species	P	F	G	F	PF	P	F	P
Palmer amaranth								
Glyphosate-susceptible	FG	E	PF	G	E	PF	G	G
Glyposate-resistant	FG	E	PF	G	E	PF	G	G
ALS-resistant	FG	E	PF	G	E	PF	N	G
Glyphosate + ALS resistant	FG	E	PF	G	E	PF	N	G
Pigweed, red root	E	E	GE	GE	E	FG	E	GE
Prickly sida	N	G	G	F	ND	N	G	P
Sicklepod	N	PF	G	F	P	N	PF	N
Smartweed	N	F	G	G	ND	N	G	N
Spurred anoda	N	G	F	F	ND	N	E	N
Tropic croton	N	G	FG	FG	FG	N	FG	N
Velvetleaf	N	F	F	PF	ND	N	E	N
Volunteer peanuts	N	P	PF	P	P	N	P	N

Note: PPI = preplant-incorporated; PRE = preemergence

E = excellent, 90% or better control
G = good, 80 to 90% control
F = fair, 50 to 80% control
P = poor, 25 to 50% control
N = no control, less than 25% control
ND = no data

[1] See Table 10-1 for brand names and Table 10-2 for application rates.

Table 10-6. Annual and Perennial Grass, Nutsedge, and Dayflower Response to Postemergence Herbicides[1]

Weed	clethodim	Fusilade DX	quizalofop	sethoxydim	glufosinate	glufosinate + Enlist One[2]	glufosinate + pyrithiobac	glyphosate	glyphosate + Engenia[3] or XtendiMax[3]	Enlist Duo or glyphosate + Enlist One[2]	glyphosate + Envoke	glyphosate + pyrithiobac	Envoke	pyrithiobac
Bermudagrass	G[4]	G[4]	G[4]	F[4]	N	ND	N	F[5]	ND	ND	F[5]	F[5]	N	N
Broadleaf signalgrass	E	GE	G	E	G	G	G	E	E	E	E	E	N	N
Crabgrass	GE	G	G	GE	G	G	G	E	GE	GE	E	E	P	N
Crowfootgrass	G	F	G	FG	G	G	G	E	GE	GE	E	E	N	N
Fall panicum	E	GE	GE	E	G	G	G	E	E	E	E	E	NP	N
Foxtails	E	E	E	E	G	G	G	E	E	E	E	E	NP	N
Goosegrass	GE	G	G	GE	P	P	P	E	GE	GE	E	E	NP	N
Johnsongrass														
Seedling	E	E	E	E	G	G	G	E	E	E	E	E	P	P
Rhizome	GE	GE	E	G	F[6]	ND	F[6]	GE	ND	ND	GE	GE	P	NP
Texas panicum	E	G	G	E	G	G	G	E	E	E	E	E	NP	N
Nutsedge														
Yellow	N	N	N	N	PF	F	F	F[5]	F	FG	E	FG[5]	G	PF
Purple	N	N	N	N	PF	F	F	FG[5]	FG	G	GE	FG[5]	FG	PF
Doveweed	N	N	N	N	P	P	P	P	P	P	ND	P	ND	N
Spreading dayflower	N	N	N	N	PF	F	FG	P	P	ND	P	FG	N	FG

E = excellent, 90% or better control
G = good, 80 to 90% control
F = fair, 50 to 80% control
P = poor, 25 to 50% control
N = no control, less than 25% control
ND = no data

[1] See Table 10-1 for brand names and Table 10-2 for application rates.

[2] Apply only to Enlist varieties.

[3] Apply only to XtendFlex varieties.

[4] Two applications may be needed for adequate control.

[5] Good control with two applications of glyphosate.

[6] Acceptable control with two applications of glufosinate.

Table 10-7. Annual Broadleaf Weed Response to Postemergence Herbicides[1]

Weed	glufosinate[2]	glufosinate + Enlist One[3]	glufosinate + pyrithiobac[2]	glyphosate	glyphosate + Engenia[4] or XtendiMax[4]	Enlist Duo[3] or glyphosate + Enlist One[3]	glyphosate + Envoke	glyphosate + pyrithiobac	pyrithiobac	Envoke
Cocklebur	E	E	E	E	E	E	E	E	G	GE
Common purslane	FG	G	G	FG	E	G	ND	G	F	ND
Common ragweed	E		E	E			E	E	P	G
Glyphosate-susceptible	E	E	E	N	E	E	G	P	P	G
Glyphosate-resistant		E			E	E				
Cowpea	G	E	E	GE	E	E	E	E	G	G
Crotalaria	ND	G	G	G	E	E	G	G	G	ND
Eclipta	G	E	E	E	E	E	E	E	G	PF
Florida beggarweed	G	G	E	E	E	E	E	E	G	GE
Florida pusley	F	G	F	PF	G	G	PF	PF	NP	P
Hemp sesbania	GE	E	ND	PF	E	G	ND	GE	GE	ND
Jimsonweed	E	E	E	E	E	E	E	E	E	N
Lambsquarters	E	E	E	G	E	E	E	G	N	G
Morningglory species										
Tall	E	E	E	FG	E	E	E	FG	P	G
Others	E	E	E	FG	E	E	E	GE	G	G
Palmer amaranth	G	E	G	E	E	E	E	E	F	PF
Glyphosate-susceptible	G	E	G	N	E	E	PF	F	F	PF
Glyphosate-resistant	G	E	FG	E	E	E	E	E	N	N
ALS-resistant	G	E	G	N	E	E	N	N	N	N
Glyphosate + ALS resistant										
Pigweed, redroot	G	E	GE	E	E	E	E	E	G	FG
Prickly sida	FG	G	FG	FG	E	G	FG	FG	F	N
Sicklepod	E	E	E	E	E	E	E	E	PF	E
Smartweed	GE	E	E	G	E	G	E	E	G	G
Spurred anoda	P	ND	G	E	E	E	E	E	G	P
Tropic croton	G	E	G	E	E	E	E	E	P	PF
Velvetleaf	F	G	G	E	E	E	E	E	G	G
Volunteer peanuts	GE	E	GE	F	E	F	FG	F	P	PF

Note: E = excellent, 90% or better control; G = good, 80 to 90% control; F = fair, 50 to 80% control; P = poor, 25 to 50% control; N = no control, less than 25% control; ND = no data

[1] See Table 10-1 for brand names and Table 10-2 for application rates.

[2] Weeds must be 3 inches or less, and Palmer amaranth 2 to 3 inches, to achieve this level of control by glufosinate.

[3] Apply only to Enlist varieties.

[4] Apply only to XtendFlex varieties.

Table 10-8. Annual Broadleaf Weed Response to Postemergence Directed Herbicides[1]

Weed	Cobra + MSMA	Cotoran + MSMA	diuron + MSMA	flumioxazin + MSMA or Fierce + MSMA	prometryn + MSMA	Suprend + MSMA	glyphosate + Aim	glyphosate + prometryn	glyphosate + diuron	glyphosate + flumioxazin or glyphosate + Fierce	glyphosate + Suprend	paraquat + diuron[2]
Cocklebur	E	E	E	E	E	E	E	E	E	E	E	E
Common purslane	G	FG	G	G	FG	ND	FG	GE	GE	GE	E	E
Common ragweed					E			E				
Glyphosate-susceptible	E	GE	E	GE		E	E		E	E	E	G
Glyphosate-resistant	E	GE	E	GE		E	PF		PF	P	G	G
Cowpea	FG	G	G	G	E	E	GE	P	GE	E	E	E
Crotalaria	G	G	G	ND	G	E	G	GE	G	ND	G	ND
Eclipta	E	G	E	E	G	E	E	G	E	E	E	G
Florida beggarweed	E	E	E	E	G	E	E	E	E	E	E	E
Florida pusley	F	F	F	FG	E	F	G	E	G	GE	G	P
Hemp sesbania	F	PF	PF	ND	F	ND	GE	G	ND	ND	ND	FG
Jimsonweed	GE	GE	G	E	PF	G	E	ND	E	E	E	E
Lambsquarters	F	G	G	FG	G	GE	GE	E	GE	GE	E	G
Morningglory species												
Tall	E	G	GE	E	G	E	E	GE	GE	E	E	G
Other species	E	G	GE	E	G	E	E	GE	GE	E	E	G
Palmer amaranth												
Glyphosate-susceptible	G	FG	G	G	F	GE	E	E	E	E	E	GE
Glyphosate-resistant	G	FG	G	G	F	GE	PF	PF	F	PF	F	GE
ALS-resistant	G	FG	G	G	F	F	E	E	E	E	E	GE
Glyphosate + ALS resistant	G	FG	G	G	F	F	PF	PF	F	PF	P	GE
Pigweed, redroot	G	G	GE	GE	G	GE	E	E	E	E	E	GE
Prickly sida	GE	FG	GE	GE	GE	GE	FG	G	G	GE	G	FG
Sicklepod	PF	G	GE	GE	GE	E	E	E	E	E	E	E
Smartweed	F	G	F	G	F	ND	GE	G	G	G	E	GE
Spurred anoda	F	FG	F	G	F	ND	E	E	E	E	E	G
Tropic croton	E	G	G	E	G	GE	E	E	E	E	E	G
Velvetleaf	F	F	F	G	F	F	E	E	E	E	E	ND
Volunteer peanuts	PF	FG	G	FG	FG	G	FG	FG	G	FG	FG	F

Note: E = excellent, 90% or better control; G = good, 80 to 90% control; F = fair, 50 to 80% control;
P = poor, 25 to 50% control; N = no control, less than 25% control; ND = no data

[1] See Table 10-1 for brand names and Table 10-2 for application rates.

[2] Applied under a hood only.

Table 10-9. Comparison of Glyphosate Formulations and Acid Equivalence

Formulation	Acid equivalent (a.e.)	Brand names[1]	Registered uses		Comparative rates	
			Burndown	RR Flex cotton	lb a.e.	fl oz
diammonium salt 3.6 lb/gal	3 lb/gal	Imitator DA	√	√	0.375 0.560 0.750 1.125	16 24 32 48
dimethylamine salt 5.07 lb/gal	4.0 lb/gal	Duramax Durango DMA	√	√	0.375 0.560 0.750 1.125	12 18 24 36
isopropylamine salt 4.0 lb/gal	3.0 lb/gal	Abundit Extra	√		0.375 0.560 0.750 1.125	16 24 32 48
		Ag Saver Glyphosate 41% Plus	√	√		
		Alecto 41-S	√	√		
		Alligare Glyphosate 4	√			
		Buccaneer	√			
		Buccaneer Plus	√			
		Cornerstone Plus	√	√		
		Credit 41	√	√		
		Credit 41 Extra	√	√		
		Crop $mart Glyphosate Extra	√	√		
		Eraser A/P	√	√		
		Farmway-Max Glyphosate 41%	√	√		
		FarmWorks 41% Glyphosate	√	√		
		Four Power Plus	√	√		
		Gly Star Gold	√	√		
		Gly Star Original	√	√		
		Gly Star Plus	√	√		
		Glyfine Plus	√			
		Glyfos X-TRA	√			
		Glyphogan	√	√		
		Glyphogan Plus	√	√		
		Helosate Plus Advanced	√	√		
		Honcho Plus	√			
		Imitator Plus	√	√		
		Mad Dog	√	√		
		Mad Dog Plus	√	√		
		Makaze	√	√		
		Makaze Yield Pro	√	√		
		Wynca USA Sunphosate	√	√		

[1] Products listed in this table were registered for sale in North Carolina in 2017.

continued

Table 10-9. Comparison of Glyphosate Formulations and Acid Equivalence *(continued)*

Formulation	Acid equivalent (a.e.)	Brand names[1]	Registered uses		Comparative rates	
			Burndown	RR Flex cotton	lb a.e.	fl oz
isopropylamine salt 5.0 lb/gal	3.75 lb/gal	Buccaneer 5	√		0.375 0.560 0.750 1.125	12.8 19.1 25.6 38.4
		Helosate 5	√	√		
isopropylamine salt 5.5 lb/gal	4 lb/gal	Cornerstone 5 Plus	√	√	0.375 0.560 0.750 1.125	12 18 24 36
		Glyfine 5 Plus	√			
isopropylamine salt + monomonium salt 3.97 lb/gal	3 lb/gal	Roughneck	√		0.375 0.560 0.750 1.125	16 24 32 48
		Showdown	√			
isopropylamine salt + potassium salt 4.5 lb/gal	4.5 lb/gal	Credit Extreme	√	√	0.375 0.560 0.750 1.125	10.7 15.9 21.3 32.0
		Envy Six Max	√	√		
potassium salt 5.0 lb/gal	4.17 lb/gal	Touchdown Total	√	√	0.375 0.560 0.750 1.125	11.5 17.2 23.0 34.5
		Traxion	√	√		
potassium salt 5.5 lb/gal	4.5 lb/gal	Abundit Edge	√	√	0.375 0.560 0.750 1.125	10.7 15.9 21.3 32.0
		Gly Star K-Plus	√	√		
		Honcho K6	√	√		
		Roundup PowerMax	√	√		
		Roundup PowerMax II	√	√		
		Roundup WeatherMax	√	√		
potassium salt 6.0 lb/gal	5.0 lb/gal	Touchdown HiTech	√	√	0.375 0.560 0.750 1.125	9.6 14.3 19.2 28.8

[1] Products listed in this table were registered for sale in North Carolina in 2017.

Table 10-10. Management Programs for Palmer Amaranth in Cotton [1,2]

Trait[2]	Tillage system	Preplant incorporated or early preplant burndown	Preemergence	First POST[3]	Second POST[3]
GL or WRF	Conventional	pendimethalin or trifluralin Incorporate no deeper than 2 inches	One of the following: Brake F16; diuron + fomesafen; Warrant + diuron; Warrant + fomesafen; Warrant + fomesafen + diuron; Warrant Ultra	glufosinate + residual[4]	glufosinate alone or with residual[5]
	No-till or strip-till	glyphosate + flumioxazin + either 2,4-D or dicamba			
RRF	Conventional	pendimethalin or trifluralin Incorporate no deeper than 2 inches	One of the following: Brake F16; diuron + fomesafen; Warrant + diuron; Warrant + fomesafen; Warrant + fomesafen + diuron; Warrant Ultra	glyphosate + residual[6]	glyphosate + residual[7]
	No-till or strip-till	glyphosate + flumioxazin + either 2,4-D or dicamba			
W3FE	Conventional	pendimethalin or trifluralin Incorporate no deeper than 2 inches	One of the following: Brake F16; diuron + fomesafen; Warrant + diuron; Warrant + fomesafen; Warrant + fomesafen + diuron; Warrant Ultra	glufosinate + residual[4]	glufosinate alone or with residual[5]
	No-till or strip-till	glyphosate + flumioxazin + either 2,4-D or dicamba		glufosinate + Enlist One	glufosinate + residual[4]
				glufosinate + Enlist One + residual[8]	glufosinate alone or with residual[5]
				glufosinate + Enlist One + residual[8]	glufosinate + Enlist One
				glufosinate + residual[4]	Enlist Duo
				glufosinate + Enlist One + residual[8]	Enlist Duo
				Enlist Duo	Enlist Duo
XF	Conventional	pendimethalin or trifluralin Incorporate no deeper than 2 inches	One of the following: Brake F16; diuron + fomesafen; Warrant + diuron; Warrant + fomesafen; Warrant + fomesafen + diuron; Warrant Ultra	glufosinate + residual[4]	glufosinate alone or with residual[5]
	No-till or strip-till	glyphosate + flumioxazin + either 2,4-D or dicamba		glufosinate + residual[4]	glyphosate + Engenia or XtendiMax
				glyphosate + Engenia or XtendiMax	glyphosate + Engenia or XtendiMax

[1] See Table 10-1 for brand names; see Table 10-2 for application rates and comments.

[2] GL = GlyTol/LibertyLink; WRF = WideStrike with Roundup Ready Flex; RRF = Roundup Ready Flex; W3FE = WideStrike 3 Enlist; XF = XtendFlex.

[3] For each program listed, a layby application of diuron plus MSMA or diuron plus glyphosate should be considered as needed.

continued

[4] Residual options include S-metolachlor, Outlook, or Warrant. See comments in text concerning application of glufosinate and tank mixes on WRF cotton.

[5] Residual options for second POST will vary depending upon what was used in first POST. S-metolachlor or Outlook may be applied overtop only once per year. Warrant may be applied overtop twice, but the total annual use from all applications cannot exceed 8 pints.

[6] Residual options for first POST: If no Palmer amaranth emerged, use S-metolachlor, Outlook, or Warrant. If Palmer amaranth is emerged in RRF cotton and is less than 1 inch tall, use pyrithiobac if you think your weeds are not ALS-resistant.

[7] Residual options for second POST will vary depending upon what was used in first POST. S-metolachlor or Outlook may be applied overtop only once per year. Warrant may be applied overtop twice, but the total annual use from all applications cannot exceed 8 pints. Only one overtop application of pyrithiobac is suggested and only where ALS resistance is not suspected.

[8] Residual options for mixture with Enlist One include Dual Magnum and Warrant.

11. MANAGING INSECTS ON COTTON

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Cotton insect pests can cause significant direct yield losses from the time of plant emergence through boll maturity. In addition, pests can indirectly cause loss; for example, bollworms and plant bugs can lower lint quality by causing maturity delays and stink bugs can both delay maturity and transmit boll rot pathogens. However, producers can keep insect damage to a minimum by following these six practices:

- Recognize the major pest and beneficial insects.
- Follow recommended scouting procedures.
- Follow recommended thresholds.
- Apply insecticides quickly after a threshold has been reached.
- Follow insecticide-use recommendations designed to stall resistance.
- Use cultural and biological controls when possible.

Insect control costs in North Carolina are lower than in some other regions of the Cotton Belt, providing our producers with an economic advantage over their counterparts elsewhere. However, sometimes thrips, plant bug, cotton aphid, stink bug, and/or spider mite feeding can result in significant yield losses.

The Boll Weevil Eradication Program began in 1978 on approximately 15,000 acres in northeastern North Carolina and resulted in the eradication of the boll weevil from the Southeast, the mid-South, and most of the Far West. However, boll weevils may still be unintentionally transported back into weevil-free areas. These "hitchhikers" are most often the result of either passive transport of weevils aboard vehicles or cotton equipment, such as cotton pickers, module builders, and module haulers. The Southeastern Boll Weevil Foundation supervises our large-scale, pheromone-trap-based Boll Weevil Containment monitoring program; however, this program is implemented by the NCDA&CS..

Because no boll weevils have been found in North Carolina for the past 19 years, the pheromone trapping density and associated containment costs have been reduced during this period. North Carolina cotton producers will likely be assessed a fee of approximately $1.00 per acre, or less, during 2018.

EARLY-SEASON INSECT MANAGEMENT

Thrips are North Carolina's and Virginia's most economically damaging insect pest complex. Because thrips have the potential to cause significant yield losses and maturity delays, this pest group must be controlled every year.

Thrips feed on cotton seedlings by puncturing the outer cells of young leaves and buds and consuming the plant juices within. Injury frequently results in ragged-looking plants with crinkled leaves. This injury stunts growth and can result in fruiting at higher positions, causing maturity delays and reduced yields. Injury resulting from thrips can sometimes be confused with, or exacerbated by, damage from preemergent herbicides. Furthermore, adult females prefer to lay their eggs in fleshy cotyledons. Just a few larval thrips emerging from these eggs can cause significant injury to true leaves as they are expanding. To prevent maturity delays or yield loss, thrips must be managed before injury is noticed. It is therefore critical to document the presence of thrips before a treatment decision is made.

Injury from thrips can also be worsened by cool conditions in the spring because slow-growing plants are exposed to thrips at a susceptible stage. In addition to cool weather, dry spring weather may inhibit the uptake of at-planting insecticides and may also result in the premature drying of alternate thrips hosts (for example, various hosts like wheat and weeds). This drying in turn may force large numbers of flying adult thrips to abandon these plants in search of younger, greener hosts, such as cotton seedlings that are already not taking up insecticides very well. Also, heavy or prolonged rains during the first few weeks after planting can speed the leaching of insecticides, resulting in poor control and increasing the need for foliar applications.

Because of the high populations and the shorter growing season in the North Carolina/Virginia region, thrips have the potential to cause significant yield losses and maturity delays. Growers must control them every year using programs that strive for excellence. Almost all cotton producers in North Carolina and Virginia used a seed treatment (Table 11-1) for thrips control in 2017, either alone or in combination with a soil-applied systemic insecticide (i.e., Admire Pro or Velum Total in-furrow). These products typically provided some degree of protection from thrips, and most thrips-active portions are all in the neonicotinoid-class of insecticide chemistry. Up until 2014, the thrips control provided by the different seed treatments was thought to be similar, on average, although a particular seed treatment could be more or less effective depending on environmental conditions. In 2014, however, it was discovered that some populations of our most common thrips pest of cotton (tobacco thrips) were more resistant to neonicotinoids than others. The same phenomenon was also documented in other states. We now know that resistance is widespread across the southern U.S. Cotton Belt, although on a local level, populations have a range of susceptibility. In practice, this finding means that you can expect neonicotinoid seed treatments and, possibly, some in-furrow applications not to work as well in some areas in 2018 as they have in the past. In some cases, we should expect complete field failures with these products. Furthermore, insecticide chemistry is important. Resistance levels to the active ingredients of imidacloprid and thiamethoxam vary across geography.

Table 11-1. Thrips Insecticidal Seed Treatment Options

Trade Name	Active Ingredients		
	Thrips Insecticide[a]		Additional Insecticide
	Name	Recommended rate (mg) per seed	
Aeris	imidacloprid thiodicarb	0.375 (imidacloprid) 0.375 (thiodicarb)	
Acceleron Standard Gaucho	imidacloprid	0.375	
Acceleron Elite Acceleron plus Poncho/VOTiVO[b]	imidacloprid clothianidin	0.375 (imidacloprid) 0.424 (clothianidin)	
Avicta Duo	thiamethoxam	0.340	abamectin
Avicta Elite	imidacloprid thiamethoxam	0.375 (imidacloprid) 0.375 (thiamethoxam)	abamectin
Cruiser	thiamethoxam	0.375	
Poncho/VOTiVO[b]	clothianidin	0.424	

[a]BayerCrop Science varieties (FiberMax and Stoneville) include an additional base insecticidal seed treatment for stored product pest control at 0.135 mg imidacloprid per seed.

[b]Poncho/VOTiVO not labeled for thrips in cotton.

Past research conducted in North Carolina and Virginia suggests that using a combination of treated seed along with imidacloprid liquid directed into the open furrow onto the seed before closing provided cotton producers a "one-and-done" (no follow-up foliar spray required for thrips) option for thrips control. However, this combination has failed in the field now, due to resistance. Hence, we strongly recommend scouting for thrips in every field in the event that a foliar application may be needed. Even when a soil-applied systemic insecticide is used, thrips often occur in damaging numbers. As mentioned before, dry weather may retard the uptake and performance of the product used. Also, extended cool weather may delay plant growth, keeping the plants susceptible longer and exceeding the time frame of the product's effectiveness. In this case, the persistence of a product's activity can be very important. Furthermore, the method of application of the in-furrow insecticide is critical. Producers who can direct liquid insecticide on the seed itself in-furrow will have more success that those who do not.

When a systemic insecticide fails to control thrips, a foliar spray is often warranted, especially on early-planted cotton. However, in some cases, a spray may give rise to other problems. Aphid and mite populations may increase, for example. In most cases, the use of an at-planting insecticide, often followed by a foliar spray, is successful. Foliar-spray-only approaches without using an at-planting insecticide are not recommended because an at-planting insecticide is far more persistent and sometimes produces higher yields. Sprays should be prioritized for fields that are most highly at risk. An online calculator has been developed and validated from years of southeastern U.S. data (climate.ncsu.edu/cottonthripsrisk). This calculator uses weather information from specific geographical areas to predict when thrips will be dispersing into cotton and how susceptible cotton seedlings will be to thrips injury. Hence, growers can use this tool to predict where cotton is most at risk on their farms, directing scouting and management efforts toward these areas.

Prior to bloom, plant bugs, or *Lygus* species, injure cotton by feeding in tender terminals and, more commonly, directly on small squares with their needlelike mouthparts, causing the squares to abort. When blooming begins, plant bugs continue to feed on squares. Feeding on larger squares may cause "dirty blooms": white blooms with darkened pollen anthers and sometimes with small circular deformities (warts) or dead tissue on the flower petals. In addition, plant bug feeding on small bolls up to approximately 11 days old may cause stink-bug-like external boll spotting and internal boll damage, such as callous growth (warts), deformed or rotted fruit, or small boll abortion. This boll injury is often identical to that caused by stink bugs. In recent years, this type of injury has become more common than the type of injury seen in preblooming cotton, especially in eastern North Carolina. Plant bugs are capable of causing all of the injury symptoms shown in Table 11-2.

Table 11-2. Plant Bug and Stink Bug Injury to Cotton Plants

Plant Stage	Plant Part	Bug Type	Injury Symptoms
Prebloom	Terminals	Plant bug	With heavy feeding, terminals may be deformed or killed (black flag), resulting in a loss of apical dominance (crazy cotton).
	Small squares		Squares yellowing, turning brown, then black, and finally aborting, leaving a scar at the fruiting site.
Blooming	Various squares		Small squares, same as above; larger squares with internal damage to pollen anthers (shows up as "dirty blooms").
	White blooms		Darkened pollen anthers (dirty blooms from plant bug feeding on large squares); petal deformations.
	Bolls	Plant bug, Stink bug	Aborted small bolls, external spotting, internal pinprick-like feeding "stings", wart-like growths, and stained lint; may cause boll rots, hard lock.

Early-season monitoring for plant bug activity, especially retention counts of small squares (approximately 1/8-inch to 3/16-inch long, including bracts), is recommended. If square retention counts remain high (80 percent or more), further sampling for plant bugs is probably unnecessary at that time. If retention rates of small, upper, and other first- or second-position squares drop below the 80 percent level, further sampling for live plant bugs may be needed. One method of sampling for missing square positions is to find one randomly selected terminal square (or its missing position) and one first- or second-position square (or its missing position). Two or three nodes from the top of the plant are inspected per plant from 25 randomly selected plants within a field (50 squares total). Sweep net sampling for plant bug adults and large nymphs typically involves the taking of 25 sweeps at eight to 10 locations per cotton field (each not less than 50 feet from the field edge) and is recommended before bloom. Be mindful of field edges along ditch banks, adjacent host plants such as weedy flowering fields, or where Irish potatoes or a substantial acreage of corn is present, especially in our far eastern counties. The above areas are likely sources of migrating adult plant bugs but should not be oversampled (nor overlooked).

Once blooming has been underway for a week or more, square retention is a less reliable indicator of possible plant bug feeding. At this point, the plant may lose squares due mostly to weather-related reasons and energy directed to bolls, rather than from plant bugs. Late-season damage from plant bugs may be assessed by monitoring cotton plants for dirty blooms, for small bolls with signs of internal bug damage, and for the plant bugs themselves via drop cloths. Examining open white flowers for the occurrence of one of more brown pollen anthers (dirty blooms) as an indication of recent plant bug feeding on large squares is not used to determine if a spray is needed, but as an indication of whether additional sampling is warranted. If the level of dirty blooms is in the range of 0 to 6 percent, further more tedious sampling for plant bugs should not be needed for five to seven days. If the level of dirty blooms exceeds approximately 6 percent, additional sampling is advised. Dirty blooms should never be used to make a spray decision because there is a time lag from when the square was injured to when the bloom occurs.

A black drop cloth (ground cloth) is the preferred method of direct sampling for plant bugs once blooming is underway. Black ground cloths are easily constructed by spraying the cloth part of the sampling device with black spray paint. The drop cloth threshold, developed and recommended by mid-South entomologists, is 1.6 to 2.6 adult plus immature plant bugs per 5 row feet (or the level contained in a 5-foot drop cloth sampled from each 2.5 row foot length on either side of the cloth) or a rounded-off level of two to three plant bugs per drop cloth sample. If nymphs, particularly late instars, are also easily seen (with the exception of the tiny first instars, which often experience high mortality), indicating that reproduction has occurred, the population is regarded as potentially more damaging to squares and young bolls.

MIDSEASON INSECT MANAGEMENT

Although technically beginning at first bloom in late June to early July, the start of the major mid-July to early-August bollworm (corn earworm) moth flight usually signals the onset of potential bollworm and stink bug damage. The bollworm-tobacco budworm complex, typically composed of mostly bollworms, is the primary target for foliar insecticides in conventional cotton. Fall and beet armyworms can cause fruit damage to cotton, in most cases resulting from moving over from dried-down weed hosts (see additional note on fall armyworm). Stink bugs are now the dominant late-season pest in *Bt* cotton varieties, although in some years, bollworms can persist through September. Because of the potential for severe boll damage from one or more of the above pests, and because cotton damaged at this time of year usually compensates little for boll damage, insect damage to bolls must be minimized during all or part of late July through mid-to-late August in North Carolina.

The first two generations of bollworms occur primarily on field corn. Third-generation (sometimes referred to as the second field, or F2, generation) moths usually emerge in large numbers from mid-July to early August when corn is drying, and they fly to the more attractive, blooming cotton. Although essentially all of the cotton now planted in North Carolina (more than 99.9 percent) is at least two-protein and three-protein *Bt* cotton, ***to date*** *no tobacco budworms have survived on a Bt cotton plant in the field from a naturally occurring tobacco budworm population*. In contrast, bollworms have always survived at low levels in Bollgard II, TwinLink, and WideStrike cotton and sometimes require overtreatment with foliar insecticide. This tendency means that in heavy bollworm years, it will be economical to apply a foliar overspray to *Bt* cotton. Furthermore, there are areas of the South, including North Carolina, where bollworms are resistant to the *Bt* toxins in Bollgard II, TwinLink, and WideStrike varieties. The extent of resistance is widespread, but even in situations where the insects are resistant, the *Bt* traits still provide some efficacy. Despite this fact, a threshold directed at eliminating larvae that hatch from eggs before they can establish on *Bt* cotton is recommended for two-toxin varieties.

Growers should be prepared to spray *Bt* cotton if bollworms break through. Although Bollgard 3 and WideStrike 3 varieties are highly effective against both tobacco budworm and bollworm, they still require follow-up sprays for larvae in heavy-pressure situations. Sprays directed against eggs will generally not be cost-effective, except in rare cases. Finally, bollworms are increasingly resistant to pyrethroids (bifenthrin is an example of a pyrethroid). However, pyrethroids still provide control in many situations. Expect less control with pyrethroids in situations where *Bt* and pyrethroid-resistant bollworm populations overlap.

Systematic, regular weekly scouting of cotton should be done for bollworms in *Bt* cotton. Weekly scouting is adequate until egg laying or light-trap catches increase, although light traps are ineffective for monitoring budworm moths. Check with your county Extension agent for possible light-trap counts for the major bollworm moth flights (in addition, the counts from approximately 15 light traps are available online during the moth flight at ipm.ces.ncsu.edu/trap-data/). Bollworms are more prevalent in areas where natural enemies have been eliminated due to sprays directed at earlier season arthropods, such as aphids, spider mites, or plant bugs.

After the upper bolls that will be harvested have become difficult to cut with a pocketknife, the field is normally safe from further bollworm attack. Fields are also normally safe from further bollworm establishment when blooms and/or nonterminal squares are less than one per 1 to 2 row feet or more. Bollworm scouting can normally be stopped at that time—usually in mid-to-late August to early September, depending on the intensity of the moth flight and the maturity of cotton plants.

Due to our low late-season spray environment in North Carolina, the native green stink bug (*Chinavia hilare*) and the native brown stink bug (*Euschistus servus*) have become more abundant and damaging since the adoption of *Bt* varieties. The most yield-reducing damage to bolls takes place during weeks three to five or six of blooming. Brown marmorated stink bug (*Halyomorpha halys*) is a new nonnative invasive stink bug found throughout the state, but only in economically damaging numbers in the NC western piedmont.

Stink bugs injure cotton by puncturing the carpal walls of bolls with their “beaks” and by feeding primarily on the soft, developing seeds. Heavy feeding on rare occasions destroys small bolls, causing them to abort. When stink bugs feed on slightly larger to medium-sized bolls (up to about 3.5 weeks old), they may introduce boll-rot pathogens, resulting in partially or entirely destroyed locks, hard-lock, and a lower grade of harvested cotton. This damage is further expressed in opening cotton under wet conditions. In contrast to the native green and brown stink bugs, both adult and nymph brown marmorated stink bugs can feed on bolls until maturity and even prefer larger-sized bolls.

Externally, boll injury is characterized by small, round, shallow, purplish depressions, usually in the 1/32-inch to 1/16-inch range. These spots tend to be larger than the tiny black gossypol gland spots. Internally, bug-injured bolls will often have a yellowish to tan to brown stain in the seed areas, often, but not always, under the external feeding spots. Other injury symptoms include small wart-like growths and/or dark “pinprick” spots on the inside of the boll wall. We recommend counting both stained lint and warts as injury, but not external boll spotting or internal “pinpricks.” Internal boll injury can be present without obvious external evidence. Also, the external boll spotting caused by stink bugs and plant bugs may be difficult to separate from other kinds of spotting on the boll surface, for example, that caused by bloom tags that adhere to the top or side of the boll.

Stink bug injury is more prevalent in fields where bollworm treatments have been minimal (that is, none or one). Because stink bug and plant bug damage to bolls is often indistinguishable, damaged bolls may be the result of feeding by either bug group. At present, stink bug injury to bolls is much more widespread than plant bug injury in most areas of the state in most years.

The distribution of stink bugs and plant bugs in a cotton field may be uneven, with bug numbers and damage higher at field edges and in rank areas, but also dispersed in a clumpy manner throughout the cotton field. Do not oversample unrepresentative areas; however, they should be noted.

A sample of 25 quarter-sized bolls (more in larger cotton fields—approximately one boll/acre) should be inspected at each scouting session, beginning at early boll development, but with an emphasis on weeks three through five or six of the bloom period.

To determine if a boll has been injured by stink bugs, the quarter-sized bolls should either be crushed by hand or cut open to examine the locks and inner boll wall surface. Except for “pinpricks,” count all internal boll injury, including stained or spotted lint and callous growth or inner boll wall warts. Current research suggests that a threshold for native stink bugs of 50

Table 11-3. Stink bug internal boll injury thresholds

Week of Bloom	Threshold (%)
1*	50 (treatment seldom justified)
2	30
3	10
4	10
5	10
6	20
7	30
8	50

*Threshold seldom met during first week of bloom

percent internal injury may be more appropriate than 30 percent during the first two weeks of blooming, as well as using higher thresholds later in the boll production period, when the ratio of larger, "safe" bolls to smaller, susceptible bolls increases (Table 11-3). Thresholds have not been established for brown marmorated stink bugs.

Cotton growers and scouts in the Southeast can use the stink bug decision aid card to assess and manage native stink bug injury based on thresholds for different cotton growth stages. This scouting decision aid was developed for use in the Southeast to encourage (1) enhanced adoption of stink bug scouting in cotton, (2) better field identification of stink-bug-induced boll damage symptoms, and (3) use of recommended scouting procedures. A card can be created by visiting the NC Cotton Insect Scouting Guide (cotton.ces.ncsu.edu/insect-scouting-guide) and printing out the photos in the scouting card section. There is also a description on how to use it in the guide. The aid relies on the latest dynamic threshold for stink bugs in cotton based on week of bloom. The use of a simple decision aid can help producers and scouts do the following:

- Select the correct boll sizes for stink bug injury assessments.
- Recognize stink bug injury.
- Follow straightforward scouting steps.
- Utilize the "dynamic" threshold to avoid yield losses and minimize unnecessary insecticide use.

The stink bug decision aid card should improve stink bug management because the dynamic threshold is based on the cotton growth stages when the crop is most susceptible to stink bug injury. The aid relies on lower thresholds during weeks of maximum susceptibility (weeks three through five of the bloom period) and higher thresholds during stages of lower vulnerability (weeks one to two and six to nine of the bloom period).

Decision aid for stink bug thresholds in Southeast cotton

❶ Pull random sample of quarter size diameter bolls, avoid field edges. (boll sizes between 0.9” and 1.1”)

❷ 1 boll / acre, no less than 25 / field.

❸ Sort bolls into two piles: those with and those without, obvious external lesions.

❹ Crack and inspect bolls with external lesions for internal damage (boll wall warts, stained seed or lint).

❺ If threshold is not met for that week, (see chart) check the remaining bolls for internal damage.

❻ Treat field only if the threshold is met for that week.

Week of bloom	Threshold (% internal boll damage)
1	**50%**
2	**30%**
3	**10%**
4	**10%***
5	**10%***
6	**20%**
7	**30%**
8	**50%**

*Consult state guidelines for scouting intervals.

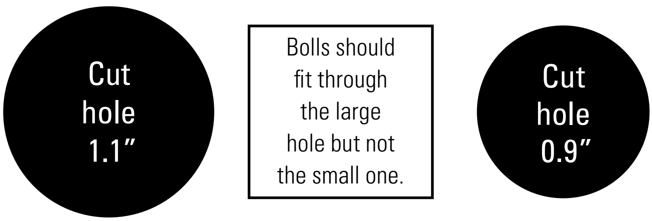
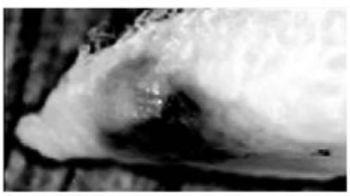
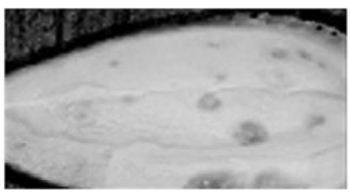


Figure 11-1. Field decision aid showing scouting procedures, boll size selection range, and internal boll injury thresholds by week of bloom.

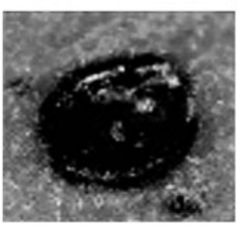
Decision aid for stink bug thresholds in Southeast cotton



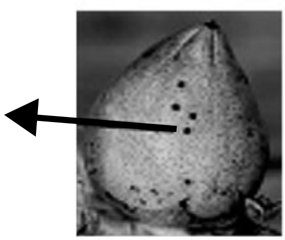
Stained seed and lint



Boll wall warts



External lesions



Quarter size boll

Figure 11-2. Aid showing external and internal stink bug injury symptoms.

Description and Use

The decision aid card (Figure 1) provides recommended scouting procedures:

1. Select a random sample of the correct size bolls.
2. Assess an adequate number of bolls.
3. Sort the bolls into two piles, those with and those without obvious external damage lesions.
4. Crack bolls between the thumb and forefinger or cut them open with a knife and inspect all internal boll wall surfaces for internal warts (not just areas visible from the initial crushing or from the initial knife cut), and examine all locks for stained lint. (Helpful hint: crack and inspect bolls with obvious external lesions first to determine if the internal damage threshold is met, as bolls with external lesions are more likely to be injured internally; assessing these bolls first can save time.)
5. If the threshold is not met, check the remaining bolls for internal injury.
6. Treat only if the threshold has been met for that week.

The measuring holes provide an efficient way to select correctly sized bolls. Cotton scouts should target bolls with an outside diameter between 0.9 to 1.1 inches. **Bolls of this size correlate best with recent stink bug injury.**

The recommended dynamic threshold is also listed by week of bloom. The asterisks for weeks four and five of the bloom period permit nuances in scouting frequency recommendations by the various southeastern states.

The card also provides images (in addition to the images of stink bug damage found on the aid itself) to help properly identify stink bug damage: internal warts and stained lint, and external damage lesions (Figure 11-2). As explained in procedure 3, above, external damage symptoms may be used to sort the pulled bolls into two groups.

If two or more consecutive scouting checks reveal stink bug damage at approximately two-thirds of the threshold level, treatment may be justified.

Once the damaged-boll threshold has been met, it may be helpful to determine if the brown stink bug (*Euschistus servus*) or green stink bug (usually *Chinavia hilare*) is the predominate species group, as brown stink bugs are more difficult than green stink bugs to control with pyrethroids.

To determine which native stink bug species is more prevalent, make general observations while scouting (in the case of high population levels), sample with a beat cloth (six 6-row-foot samples or more until adequate stink bug numbers are observed), or use a sweep net (sample until adequate numbers of stink bugs are observed). Because these observations or samples are conducted solely to determine if the stink bugs are brown or green, they may be done quickly and include visual observations. For beat cloth sampling, a 3-by-3-foot, or 3-by-2.5-foot, beat cloth is unfurled between two adjacent rows, and the cotton plants in the two adjoining rows are beaten or shaken over the cloth, causing the large nymphs and adults to fall onto the cloth so they can be counted. Count any adult stink bugs seen flying if the color can be distinguished. In sweep net sampling, individual sweeps should be made with firm, pendulum-like motions (handle up, net down), swinging down with both hands through the upper middle canopy while walking down the row. If the sweeping motion is correct and vigorous enough, some bolls and leaves usually will be knocked into the net. In either of the above approaches of assessing live stink bugs, count adults and large nymphs. This quicker sampling may be stopped once an adequate sample (approximately 10 stink bugs) has been counted.

As the proportion of large "native stink bug safe" bolls increases relative to the smaller susceptible bolls during the end of July and throughout August and early September, the threshold may be raised, as indicated in Table 11-1 and in Figure 11-1. Once-a-week scouting for stink bugs on *Bt* (or minimally treated) cotton is recommended under most situations.

TRANSGENIC COTTON

The two-protein *Bt* lines represented by Bollgard II, TwinLink, and WideStrike varieties, and the three-protein *Bt* lines represented by Bollgard 3 and WideStrike 3, manage only caterpillars, not other pest insects, such as thrips, cotton aphids, plant bugs, and stink bugs. Also, different caterpillar pests are not controlled to the same degree. For example, field tests have shown that tobacco budworms attempting to feed on *Bt* cotton lines in the field are all killed (at least for the time being). However, bollworms can damage squares and bolls, though generally at a low rate. The two-protein *Bt* technology typically provides good control of both armyworm species; however, see the later section on fall armyworms. In Bollgard 3 and WideStrike 3 cotton, unless bollworm pressure is very high and chemical disruption has occurred (such as an overspray with Bidrin or Orthene just prior to or during the moth flight), sprays for bollworms may not be needed. Due to increasing *Bt* resistance and bollworm abundance, Bollgard II, TwinLink, and WideStrike varieties may need treatment.

Because beneficial insects are not adversely affected by *Bt* cotton, their abundance and impact have increased in situations where disruptive insecticide applications are either less frequent or not made. Higher beneficial insect numbers present with fewer sprays for caterpillars have led to somewhat more effective suppression of third-generation bollworms and other caterpillars in *Bt* cotton lines.

COTTON

The planting of Bollgard cotton varieties is no longer permitted in the United States. Essentially all cotton planted, with the exception of limited conventional cotton, will be composed of two-protein *Bt* varieties (Bollgard II, TwinLink, and WideStrike) and three-protein *Bt* varieties (Bollgard 3 and WideStrike 3). A non-*Bt* cotton refuge is not required for multiple *Bt* protein varieties.

The effectiveness of *Bt* proteins against North Carolina's major caterpillar pests is influenced by several factors, including the pest in question, the level of *Bt* susceptibility of the particular populations, the level of *Bt* protein expression in the fruiting forms, the level of supplemental, beneficial insect "help," and the phenology or maturity of the cotton crop. Under irrigation, if high rates of nitrogen have been used, and/or if a beneficial-insect-reducing spray is applied just before or early in the bollworm moth flight (for example, a spray for stink bugs), moderate to occasionally heavy bollworm establishment may occur with associated significant yield reductions. It is also worth noting that bioassays conducted on bollworms from North Carolina during 2016 and 2017 showed that bollworm populations had ranges of *Bt* susceptibilities that were as much as 100× different. Depending on the bollworm population that is present, a huge difference in survival on *Bt* cotton can be expected.

The stacked, two-protein *Bt* varieties (presently Bollgard II and WideStrike) and three-protein *Bt* varieties (Bollgard 3 and WideStrike 3) also provide good to excellent control of beet and fall armyworms (see information under the fall armyworm section) and cabbage and soybean loopers, but not early-season cutworms.

SCOUTING TRANSGENIC COTTON

A few cotton scouting suggestions are indicated below:

1. **Use an egg threshold for the major bollworm generation:** Bollworms must hatch from eggs and consume enough of the *Bt* toxin to be killed. However, in cases where bollworms are resistant to *Bt*, they can establish, and control with foliar insecticides becomes much more difficult. *Bt*-resistant bollworms can be controlled using a foliar application of chlorantraniliprole, if it is applied early before larvae establish. Two disadvantages of this approach are that populations may not be resistant to *Bt* or the eggs may be from tobacco budworm (which is 100 percent controlled by *Bt* cotton) rather than bollworm (see "Thresholds").
2. **Use of "multiple pest thresholds" is encouraged**: If sub-threshold levels of different pests add up to or exceed a one-pest threshold, treatment is advised (for example, 40 percent of the bollworm threshold and 75 percent of the stink bug threshold equal 115 percent, or more than 100 percent of the treatment threshold). Selection of the appropriate insecticide should target products that are active again both insect groups.
3. **Focus on second instar bollworms**: The point at which *Bt* cotton lines may require a supplemental insecticide for caterpillar control will be the point at which bollworm establishment occurs at a potentially high enough level to cause economic loss. Thus, it will be essential to recognize the difference between both the first and second bollworm stages, and to respond only to bollworms that are second stage larvae or larger (1/8-inch and longer).
4. **A high proportion of the bollworms that become established often do so under red flowers and bloom tags.** This tendency is a very common "trigger" for treatment. In monitoring blooms and bloom tags, however, remember to raise the 3 percent bollworm treatment threshold according to the ratio of total bolls to bloom-tagged bolls. For example, if bloom tags represent 10 percent of the sampled boll population in the field, if a bollworm is present under each of these bloom tags, and if no bollworms are found on the remaining

(non-bloom-tagged) sampled bolls, then sampling only bloom tags (100 percent bloom tags) would result in overestimating the bollworm population in the field tenfold. In this case, the treatment threshold for this sample containing only small bolls with bloom tags should be raised from 3 percent to 30 percent. On the other hand, the threshold for bollworms on *Bt* cottons is low—it takes very few worms under bloom tags in late July to mid August to justify treatment.

5. **Scouting for other insects**: Stink bugs and plant bugs have, in the absence of insecticides directed toward bollworms, become more numerous and require more intensive scouting than they would in conventional, more frequently treated, cotton. Weekly scouting is recommended, with a subsample of fields assessed twice weekly to detect cases of rapid establishment.
6. **Beneficial insects**: Beneficial insects will likely be more abundant in untreated or less-treated *Bt* cotton if early season insects, such as plant bugs, have not been sprayed. Their identification and population levels should be at least informally monitored.
7. **Summary**: Bollgard II, TwinLink, and WideStrike varieties require (1) no scouting for tobacco budworms, (2) there should be an emphasis on the appearance of bollworm eggs, and (3) a major emphasis on stink bugs and plant bugs as the triggers for foliar insecticide treatment. Bollgard 3 and WideStrike 3 varieties require (1) no scouting for tobacco budworms, (2) there should be an emphasis on the appearance of second instar bollworms, and (3) a major emphasis on stink bugs and plant bugs as the triggers for foliar insecticide treatment. Scouting for European corn borer damage is no longer required.

MANAGEMENT OF MISCELLANEOUS INSECTS

Aphids

Cotton aphids are an occasional headache for cotton producers. Neonicotinoid insecticides (Assail, Belay, Centric, Admire Pro, and Strafer Max) are becoming less effective. Because this insecticide class is used in both cotton seed treatments and for other cotton insects (i.e., plant bugs), aphid resistance to this somewhat-new class of insecticides is a concern, with confirmed resistant populations detected in eastern North Carolina. The insecticide Carbine, which provides aphid control similar to the neonicotinoids, is listed as having a different mode of action (MOA classes 9C and 4C) and thus may provide an alternative to the neonicotinoid class of insecticides (MOA class 4A).

Fortunately, high levels of aphid mummifying parasites and the fungus *Neozygites fresenii* that in most cases hold or reduce aphids to subeconomic numbers are common in our region, often becoming established in the second or third week of July. The combination of predators, parasites, and fungi usually justifies our general recommendation not to treat cotton aphids, except under dry, stressed conditions, very high aphid levels, and little or no evidence of mummies or the fungus. Note that the increase in early and mid-season sprays directed at plant bugs in recent years has reduced the incidence of parasites and predators that can hold aphids back. In cotton with open bolls, aphid-caused sooty mold or sticky cotton (from the heavy presence of honeydew) may become a problem, though not typically in the Southeast. After the defoliant has been applied, however, cotton aphids are typically only present at very low levels.

On the Aphid Rating Scale, a level of 4 or higher in cotton just before opening, plus honeydew presence, along with low levels of mummies or the fungus, may be a good indicator of the need to treat (see Aphid Rating Scale, Table 11-4). Treatments for cotton aphids have been low for the past 10 years.

Table 11-4. Aphid Rating Scale

0	No aphids.
1	Occasional plants with low numbers of aphids.
2	Plants with low numbers common; heavily infested plants rare; honeydew visible occasionally.
3	Most plants with some aphids; occasional plants heavily infested; honeydew easily visible in most areas of the field.
4	Heavily infested plants common; aphids clumped on upper leaves; honeydew common; cotton under stress.
5	Many heavily infested plants; infestations are on most plants in large areas of the field; cotton under stress.

Spider Mites

Spider mite damage, rare in North Carolina in most years, but sometimes more common on cotton in the northeastern peanut-production counties or in our far eastern counties, can occur almost any time during the season and is usually more prevalent during dry conditions and on sandy soils. Mite damage appears as a slight yellow stippling of the leaves, which later changes to a reddish or bronze color. Mite damage also can be recognized by the presence of fine webbing on the undersides of the affected leaves. This webbing, if present on lower leaves, often traps blown sand grains in seedling cotton. In severe infestations, the damage can cause widespread leaf yellowing, followed by bronzing and defoliation, often beginning with lower leaf drop.

Visual spot checks for mites can be made while scouting for other pests. Initial mite infestations often occur at field borders adjacent to drying corn, weeds, or mowed ditch banks or roadways, although with the widespread adoption of strip-till and no-till cotton, spider mites can sometimes build up throughout cotton fields. Even with obvious yellowing and defoliation, the presence of an active mite population in the field should be confirmed before treating. A hand lens of 10× magnification or greater is indispensable when scouting for these tiny arthropods and their eggs and in identifying the fungal parasite. In treating for mites, one to two expensive applications with excellent coverage are sometimes required and often provide only fair control. A fungus that preys on mites is often present, particularly under rainy or humid conditions, and may greatly reduce mite numbers while the damage symptoms are still present. Do not spray if rain is likely.

Fall Armyworms and Beet Armyworms

The presence of fall armyworms and their damage are recorded as part of bollworm scouting.

Additional samples are usually unnecessary. Damage from fall and beet armyworms is typically low or absent in Bollgard II, TwinLink, WideStrike, and Bollgard 3 and WideStrike 3 cotton varieties, with the rare exception of (1) beet armyworms moving into adjacent cotton from pigweed infestations, or (2) fall armyworms moving over into cotton from weed hosts. However, fall armyworm larvae resistant to one of the two proteins in WideStrike cotton (Cry1F) were found on field corn in eastern North Carolina in 2013 through 2016. How widespread this resistance is in North Carolina going forward and to what extent this resistance may affect cotton is unknown at this time. However, fall armyworms are usually only a sporadic pest of cotton, even back in the conventional cotton days. Because fall armyworms migrate into North Carolina from farther south, their numbers vary greatly from year to year and normally reach higher levels in the southern and far eastern counties.

Beet armyworms are rarely cotton pests in North Carolina in two-protein *Bt* cotton, although a few are noted on cotton almost every year, though usually at low levels.

Loopers

Cabbage and soybean loopers rarely damage cotton in North Carolina because they prefer foliage, are prone to virus attack (less so with the soybean looper), occur sporadically, and seldom become established on two-protein and three-protein cotton varieties. In conventional cotton, observing foliage during routine late-season scouting for other pests in most cases suffices for looper monitoring.

If significant leaf feeding is seen, the average percentage of defoliation across the entire field should be recorded. As a general rule, if defoliation exceeds 30 percent in cotton with a significant portion (25 percent or more) of the bolls still immature and filling out, treatment may be needed. Soybean loopers are not controlled with pyrethroids. Fortunately, Bollgard II, TwinLink, WideStrike, and Bollgard 3 and WideStrike 3 cotton lines provide excellent resistance to loopers.

Beneficial Insects

About a dozen beneficial insects are commonly found in North Carolina cotton: ambush bugs, big-eyed bugs, minute pirate bugs, green lacewings, two species of ladybird beetles, and several types of spiders. They are of two types: (1) predators that prey upon an insect pest or (2) parasites that live within the host insect. These insects, particularly the predators, reduce the number of eggs and larvae of bollworms and other caterpillars, as well as cotton aphids. Because these allies lessen the impact of pest insects, common sense dictates that producers use them as a management tool. Their presence often means that growers can delay—and, on occasion, eliminate—some insecticide applications, particularly aphid treatments.

Many complex factors are involved in determining just how many of each beneficial insect species are needed to influence a given level of pests. Therefore, it is usually not practical to assess the value of these insects except in a very general way. That is, if relatively high numbers of beneficial insects are consuming a large proportion of aphids or bollworm eggs and larvae, the treatment threshold will be reached later than would otherwise be the case, reducing the number of insecticide applications needed. Or in the case of fungal pathogens attacking spider mites or cotton aphids, the finding of even small amounts of the pathogen may signal the beginning of an epizootic that often reduces pest levels significantly over a widespread area. By the same token, beneficial insects appear to have only a limited impact on stink bugs and plant bugs in most situations.

Presently, the careful observation of sound economic thresholds offers the producer the best odds of balancing beneficial insect numbers against damaging insects. Cotton aphid infestations are usually best managed by avoiding insecticides and allowing beneficial insects and fungi to limit populations.

CULTURAL CONTROL OF COTTON INSECTS

Fortunately, most of our agronomic and weed management recommendations geared toward providing the cotton crop a fast start, rapid development, and early maturity also aid in the management of late-season insects, particularly bollworms and stink bugs. Practices that encourage early maturity, such as avoidance of June planting, render the cotton plant less attractive to moths and bugs and less attractive and susceptible to boll damage. In our fall boll-damage surveys, late rank plants often sustain two to four times the damage of those that mature early. These are a few recommended cultural practices:

1. **Matching varieties to soil type—**Some mid-season and late-season varieties can grow excessively large, rank plants, precipitating late-season insect problems; reserve these varieties for earlier planting and/or sandy soils.
2. **Avoidance of late planting—**While employing the earliest possible planting date is not critical (and may result in higher thrips damage), avoidance of late planting (after the fourth week in May) can have a dramatic effect on minimizing late-season insects. This avoidance of late planting is the single most important cultural factor in reducing late-season insect damage.
3. **Adherence to recommended nitrogen levels—**High levels of nitrogen, particularly when coupled with late planting and high rainfall levels, can trigger rank cotton growth and high bollworm populations on conventional cotton and higher stink bug and plant bug levels on *Bt* cottons.
4. **Use of PGRs (plant growth regulators)—**The use of mepiquat chloride and other similar products on fields with either a history of rank growth or a propensity for fast plant growth hastens maturity and may facilitate late-season insect control.
5. **Reduced tillage—**Thrips populations tend to be lower in reduced till environments. While the exact mechanism is not known, thrips densities are generally highest in conventional till situations. In reduced till, plants also tend to grow taller, and moisture is preserved for the roots. This moisture retention can help plants that may have been stunted by thrips

(aboveground stunting also reduces root mass) by allowing roots to access more moisture during critically dry spring conditions.

THRESHOLDS

A threshold is the level of plant damage or the number of insects at which treatment is recommended—that is, the level at which treatment will pay for itself. Threshold numbers are usually expressed in terms of the percentage or number of insects or instances of damage observed per sample (such as a given number of bolls, sweep net samples, or drop cloth samples). Often based on years of research, these thresholds form the basis for sound treatment decisions. Thresholds, however, are only general guidelines applicable to the entire state. A knowledgeable consultant or advisor may be able to modify a threshold, depending on the region of the state, its history of insect problems, and the amount of risk that the consultant and the farmer are willing to take. Also, these thresholds are refined periodically based on new research. Current thresholds for the important cotton pests are as follows:

Thrips

- On cotton from the cotyledon to the fifth-true-leaf stage: An average of two immature thrips per plant. Alternatively, an average of one immature thrips per plant for each one true leaf.
- Timing of thrips applications, especially following seed treatments, is often best targeted right before the first-true-leaf stage.

Plant Bugs

Prebloom thresholds to be used when square retention rate drops below 80 percent. From initiation of squaring until the first or second week of blooming:

- Eight plant bugs per 100 sweeps.
- The sweep net threshold may be raised to 10 if fruiting begins on nodes four through six or lowered to six to seven if fruiting begins on node eight or higher. Thresholds also may be lowered somewhat in stressed cotton.

Postbloom thresholds

- 0 to 6 percent dirty blooms—No additional scouting for plant bugs is indicated for five to seven days. Count any brown anthers as damaged. This “threshold” should be used along with other assessments, if indicated. Higher dirty bloom levels indicate need for additional assessments (with a ground cloth).
- 10 percent to 50 percent initial internal damage to quarter-sized bolls based on week of bloom, as part of stink bug sampling. (See Figures 11-1 and 11-2.)
- Two to three adults and medium to large nymphs per 5 row feet with a black beat cloth (ground cloth). (Sweep net thresholds for plant bugs in postbloom cotton typically underestimate the levels of immature plant bugs.)

Cabbage and Soybean Loopers

- 30 to 35 percent defoliation and presence of more than 25 percent immature bolls.

Spider Mites

- General leaf discoloration (chlorosis, bronzing, or both), plus live mites over most of the field and defoliation from mites in 25 percent or more of the field. (If rain is imminent, delay treatment and reevaluate three to four days after the rain. If a miticide is used, two applications are sometimes necessary.)

Stink Bugs

Damaged Bolls (dynamic threshold)

- 10 to 50 percent stink bug internal damage to quarter-sized bolls (see Table 11-1). The higher thresholds are used during the initial two weeks of blooming or later in the season to reflect advancing boll maturity (see Table 11-2 and Figure 11-1). The lower 10 percent threshold is advised during weeks three to five of blooming. Yield losses resulting from stink bug damage are less likely during the initial two weeks and final weeks of blooming.

Beat Cloth (shake cloth; black) and Sweep Net (15-inch diameter)

- *These devices should be used only to confirm the presence of green versus brown stink bugs and are thus technically no longer employed to determine if threshold levels are present*.

Conventional Cotton—Bollworms and Tobacco Budworms

Prebloom (with Bollgard II, TwinLink, WideStrike, Bollgard 3, and WideStrike 3 cotton, early season June damage from bollworm and tobacco budworms is essentially nonexistent). On our few remaining acres of conventional cotton, limit a possible treatment to one well-timed application of a nonpyrethroid, such as Blackhawk, Prevathon, Steward, or Denim. Treatment before bloom seldom pays, however.

- 15 bollworms per 100 terminals.

  or
- Eight bollworms per 100 squares.

Postbloom Egg Threshold (after the onset of the major bollworm moth flight):

- 10 or more eggs per 100 terminals.

  or
- Two to three eggs per 100 fruiting forms.

Postbloom Larval Threshold (usually after the egg threshold has been employed, but also used after blooming begins and before major bollworm flight, particularly if tobacco budworms are present):

- Three live worms per 100 fruit (squares, blooms, or bolls).

Transgenic Bt Cotton (used against the major bollworm generations)

Egg Threshold:

- 25 bollworm eggs on 100 terminals, stems, or fruit (squares/blooms/bloom tags/bolls)

Larval Threshold:

- Three second-stage (1/8-inch or larger) bollworms per 100 squares or bolls. Pay particular attention to bollworms in or under yellow, pink, and dried blooms, but sample only in proportion to their occurrence.

  or

- Two second-stage bollworms (as above) on two consecutive scouting trips.
  or
- One second-stage bollworm (as above) on three consecutive scouting trips.

Fall Armyworms (conventional cotton)

Same as the postbloom larval threshold for bollworm but may be revised upward late in the season (after September 1). The fall armyworm is primarily a late-season cotton pest. Pay particular attention to the small, grayish, fuzzy egg masses deposited on the undersides of leaves and to “window-paning” in the bracts of lower bolls and blooms for the presence of larvae. Correct identification is critical; many bollworm insecticides are ineffective against fall armyworms.

European Corn Borers (conventional cotton)

Use of the old bollworm egg threshold (10 percent eggs in terminals or 2 to 3 percent down in the canopy, or on blooms) will often control much of the late ECB generation on conventional cotton. *Bt* cotton lines are seldom damaged. Follow the more detailed guidelines in the Cotton Insect Scouting Guide (ENT-cot-6): cotton.ces.ncsu.edu/insect-scouting-guide/.

Beet Armyworms (conventional cotton)

- 10 percent live beet armyworms in squares, blooms, or small bolls in blooming cotton.
  or .
- 10 beet armyworms per foot of row later in the season (when squares and blooms will not produce harvestable bolls).
  or
- 15 percent of blooms with one or more live larvae.

Cotton Aphids

- Using the Aphid Rating Scale, treat at a rating of 4 in opening cotton (15 percent open bolls or greater) or at a rating of 5 in pre-opening cotton if plants are under stress or stunted and if aphid mummies and fungi are at low levels. Treatment is discouraged under most circumstances because of its deleterious effect on beneficial predators and parasites that attack aphid populations. In opening cotton, treat only if plants are heavily infested and honeydew is detected in significant portions of the field.
- The Aphid Rating Scale may help define situations where treatment may be indicated.

RECOMMENDATIONS

A complete listing of recommended insecticides for use in controlling cotton insects may be found in the *2018 North Carolina Agricultural Chemicals Manual.*

12. COTTON DEFOLIATION

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Defoliation is the application of chemicals to encourage or force cotton leaves to drop from the plant in order to harvest the crop in a timely manner. Defoliation is a balancing act between killing the leaves and not affecting the leaf. For successful defoliation, the leaf must stay alive long enough to begin the formation of an abscission zone that results in leaf drop. If the leaf is killed too rapidly, the chemical signals are not sent from the leaf to the abscission zone. The result is a leaf that is frozen or "stuck" to the plant, creating unnecessary trash.

Proper defoliation is a profitable part of a total cotton management system. Benefits include:

1. Elimination of the main source of stain and trash, resulting in better grades.
2. Faster and more efficient picker operation.
3. Quicker drying of dew, allowing picking to begin earlier in the day.
4. Straightening of lodged plants for more efficient picking.
5. Retardation of boll rot.
6. Potential stimulation of boll opening, which can increase earliness, yield, and profit.

DEFOLIATION DECISIONS

Harvest-aid application decisions are made based on crop maturity, crop condition, weather conditions, and desired harvest schedule. Once producers decide that defoliation is needed, they must determine when the chemical should be applied, what material(s) will be applied, and how much of each material to apply. Crop condition and air temperatures will largely determine the selection of defoliation materials and rates. Still, desired defoliation materials and rates of application often change during the season with changes in crop condition and weather. In the end, the two most important factors in determining when to defoliate are crop maturity and desired harvest schedule.

When to defoliate?

Poor defoliation can be economically costly. Defoliating too early lowers yield and fiber quality or micronaire. Defoliating too late increases the likelihood of boll rot and lint damaged or lost due to weathering. Defoliating too late also increases the possibility that defoliant activity may be inhibited by lower temperatures.

It is generally safe to defoliate when about 60 percent of the bolls are open. But this strategy may not work well in situations where the crop is set faster or slower than normal. Example

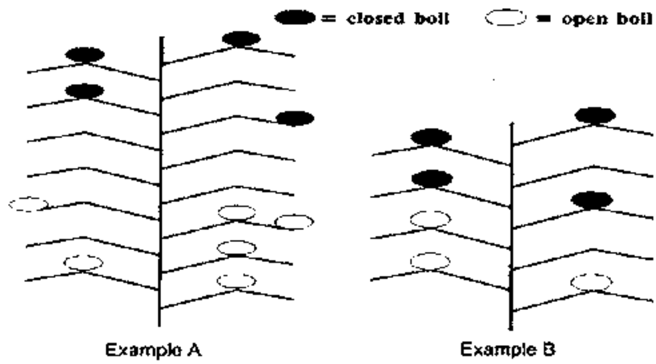

Figure 12-1. Examples of when to defoliate.

A in Figure 12-1 illustrates that a crop set over a long period may have a fruiting "gap" due to fruit loss associated with stress or insect pressure at peak bloom. This type of crop may have a high proportion of immature bolls at 60 percent open. Defoliation at 60 percent open would cut short the development of the top bolls and reduce yield and micronaire. On the other hand, Example B illustrates that a crop set in a short period of time, such as three weeks, could safely be defoliated at 40 to 50 percent open boll, as unopened bolls may be sufficiently mature and thereby safe for defoliation to occur.

Another method that is often used to time defoliation is counting the nodes above cracked boll (NACB). This is done by selecting plants with a first-position cracked boll (cracked enough that lint is visible) and counting the nodes above the cracked boll up to the highest node that has a harvestable boll. This technique places more emphasis on the unopened portion of the crop than the percent open. A count of four NACB is usually safe for defoliation. If you have low plant populations (less than two plants per foot of row), a count of three NACB would be safer. Low plant population results in a less mature crop because of the number of bolls set on vegetative branches and outer positions of the fruiting branches.

No matter which technique is used, producers should also cut and examine unopened bolls to ensure that harvestable bolls are mature. Bolls need 40 to 60 days to mature, depending on temperature. In cool weather, bolls will need extra time to mature. A boll that is set in July or early August will mature in about 40 to 45 days, whereas a boll set in mid August through early September may require about 50 to 60 days to mature. In North Carolina, bolls set (white bloom) after August 20 to 25 are likely to never mature, depending on heat unit accumulation during the fall. Producers should walk each field, decide which bolls they intend to harvest, and examine these bolls to determine whether they are mature. The younger bolls in question will be the bolls toward the top and outer portions of the plant. Bolls will be mature enough for defoliation when the following conditions occur:

1. Bolls are hard and difficult to slice into cross sections with a sharp knife. The fibers should string out when the boll is cut. If the fibers do not string out, the boll is not mature. Mature bolls should be firm when pressed, with little moisture remaining inside.

2. The seed coat is light-brown, and the kernel completely fills the seed cavity with no jelly in the center. The seed coat is a pearly-white in young bolls and turns from white to black as the boll matures. When the seed coat becomes light-brown, the boll is mature enough not to be adversely affected by harvest-aid chemicals.

Defoliation should be coordinated with picker availability. Applications should be timed so that harvesting can keep up with defoliation. In general, defoliate only as much acreage as can be harvested in about 12 to 14 days. Early defoliation of excess acreage can decrease yields, expose lint to weather more than necessary, and increase the likelihood of significant regrowth. When harvesting capacity is low for the acreage involved, consider abandoning the “once-over” strategy and plan to “scrap” or “second-pick” the acreage picked during the first week. Doing so may improve grades and prevent losses should unfavorable weather shorten the harvest season.

Defoliants work best on mature cotton under warm, humid, sunny conditions. Cool temperatures at the time of application and for the three to five days afterward can retard the activity of defoliants and cause less than desirable defoliation. If possible, defoliants should not be applied during cool snaps or cloudy weather, or when both occur. Better defoliation will occur if you can wait for a sunny, warm spell that is predicted to last for at least three to four days.

HERBICIDAL VERSUS HORMONAL DEFOLIANTS

Defoliants can be categorized as having either herbicidal or hormonal activity. Aim, Blizzard, Def, ET, Harvade, and Quickpick are herbicidal-type defoliants that injure the plant, causing it to produce ethylene in response to this injury. The ethylene promotes abscission and leaf drop. If these defoliants are applied at rates too high for the temperature, they kill the leaf too quickly before ethylene can be produced. This lack of ethylene production results in desiccation or “leaf stick” instead of the desired defoliation (leaf drop).

Dropp, FreeFall, Klean-Pik, Finish, CottonQuik, and Prep are hormonal defoliants that result in increased ethylene synthesis by the plant. Prep releases ethylene, which stimulates further ethylene synthesis in the plant, resulting in abscission zone formation in the boll walls and leaf petioles. Thidiazuron (Dropp, FreeFall, Klean-Pik, and other generics) is a type of hormone called a cytokinin. Although cytokinins promote leaf health in most plant species, in cotton and related species such as velvetleaf, cytokinins promote ethylene synthesis and act as a defoliant. Because these hormonal-type defoliants bypass herbicidal injury, they are not as likely to cause desiccation (leaf stick) as herbicidal defoliants.

DEFOLIATION MATERIALS

Sodium chlorate. Sodium chlorate is generally not used as a defoliant on spindle-type picked cotton in North Carolina. Leaf sticking may occur with high application rates, and at normal rates, sodium chlorate is usually not as effective as other defoliants. It is not a strong inhibitor of terminal regrowth and is not very effective on young, immature leaves. It is probably used most in the rainbelt to defoliate older, mature leaves. **Do not mix sodium chlorate with surfactants, oils, insecticides, or other defoliants.**

Aim. Aim is a PPO-inhibitor herbicidal type defoliant that appears to be similar to Def 6 and Harvade and is probably most similar to Harvade as it does not appear to be as rate dependent as Def 6. It appears that Aim could be used to replace any of these defoliants in defoliation mixtures. Aim has excellent desiccation activity on juvenile growth. But, like other herbicidal defoliants, Aim does not prevent regrowth. As Aim appears to be fairly hot in early research, growers may need to be careful in fields with conditions that are prone to desiccation, such as rank juvenile growth or high temperatures. The label states that Aim should be applied with a 1 percent by volume crop oil. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation. Aim appears to have good activity on morningglories.

Blizzard. Blizzard is a PPO-inhibitor herbicidal-type defoliant similar to Aim, ET, and Resource. Blizzard has excellent desiccation activity on juvenile growth. But, like other herbicidal defoliants, Blizzard does not prevent regrowth. Blizzard can be tank-mixed with ethephon-based products. Similar to other PPO-inhibitor defoliants, Blizzard should be very useful in desiccating juvenile foliage and as a second application prior to harvest. A crop coil concentrate or surfactant should be added to tank mixes containing Blizzard.

CottonQuik/FirstPick. CottonQuik and FirstPick contain the boll opener ethephon, plus urea sulfate that acts as a synergist to improve the defoliation characteristics of ethephon. CottonQuik and FirstPick will provide defoliation of mature leaves and have excellent boll-opening activity, especially compared to other products when temperatures are cool. CottonQuik can be tank-mixed with Dropp or FreeFall if regrowth is expected. Acceptable defoliation with CottonQuik alone requires cutout cotton with mature leaves. Under adverse conditions, with rank growth or with juvenile growth, a tank mixture with another defoliant will improve defoliation with CottonQuik.

Def 6 or Folex. This phosphate-type material has been a standard defoliant for several years in North Carolina. It provides effective, economical defoliation over a wide range of environmental conditions. Def or Folex is very effective in removing mature leaves but does not inhibit regrowth. It is more effective on young, immature leaves than sodium chlorate but is less effective than Ginstar, Dropp, or FreeFall. Leaf removal is rapid, and a rain-free period of two hours is sufficient for phosphate-type defoliants. The use of surfactants or crop oil has only enhanced the performance of these materials under very adverse conditions.

Dropp, FreeFall, Klean-Pik, other generics. These products contain the active ingredient thidiazuron, which candefoliates mature leaves essentially as well as the phosphate-type defoliants, especially in warm temperatures. However, thidiazuron products also provide excellent removal of juvenile growth and strong regrowth inhibition. A minimum of 0.05 lb active ingredient per acre is needed for 10 to 14 days of regrowth inhibition. Higher rates (0.1 lb a.i./A) will result in longer periods (up to 21 days) of regrowth inhibition. Thidiazuron products are slower-acting than the phosphate materials and are more sensitive to cool weather. The labels state that when nighttime temperatures fall below 60°F, less than desirable defoliation can result. Tank-mixing thidiazuron plus adjuvants such as petroleum-based crop oils has been shown to improve performance during low nighttime temperatures (60°F to 65°F). Also, tank-mixing Dropp or FreeFall plus the phosphate defoliants or Prep will enhance defoliation during cool conditions. A crop-oil concentrate should not be used when a phosphate insecticide or Def, Folex, or Prep is tank-mixed with Dropp or FreeFall.

Products containing thidiazuron require a 24-hour rain-free period. The addition of 2 to 4 ounces of Def will reduce the rain-free period required by Dropp or FreeFall alone. Make sure to follow the label instructions for tank cleanup when using Dropp or FreeFall. Failure to follow label tank-cleaning instructions may cause premature defoliation of cotton when the sprayer is used the following year. When tank-mixing thidiazuron with organophosphates (phosphate insecticides, Def, Folex), the use of 0.5 percent nonionic surfactant is recommended by the manufacturers to improve tank cleanout.

A minimum of 0.05 pound active ingredient per acre of thidiazuron will provide regrowth control for a short period (10 to 14 days). Higher rates such as 0.1 pound active ingredient per acre are needed for longer periods of control.

Thidiazuron is produced in dry and liquid formulations. At equivalent rates of active ingredient per acre, defoliation and regrowth control activity of liquid and dry formulations are similar. Limited research has indicated that the liquid formulations may be more prone to low levels of leaf desiccation when applied in combination with higher rates of Def and/or crop oil concentrate. Table 12-1 can be used to determine equivalent rates of thidiazuron in liquid and dry formulations.

Table 12-1. Equivalent rates of thidiazuron in liquid and dry formulations

Active ingredient (lb/acre)	Liquid Formulations (oz product/acre)	Dry Formulations (lb product/acre)
0.05	1.6	0.10
0.075	2.4	0.15
0.10	3.2	0.20

ET. ET is a herbicidal defoliant that is similar to Aim, Def, or Harvade. ET appears to be rather hot and may cause desiccation, especially in rank cotton. The label states that ET should be applied with a crop oil. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation. ET appears to have good activity on morningglories.

Finish. Finish contains the boll opener ethephon, plus cyclanilide that acts as a synergist to improve the defoliation characteristics of ethephon. This synergist is different from the one found in CottonQuik/FirstPick. Finish will provide defoliation of mature leaves and has excellent boll-opening activity. Finish also displays a level of regrowth control. Finish provides good terminal regrowth control, but basal regrowth control is not comparable to products that contain thidiazuron.

Ginstar, Adios, Cutout, Redi-Pik, other generics. These products include thidiazuron (active ingredient in Dropp) and the herbicidal defoliant Diuron. Defoliation is faster than with Dropp alone, especially in cooler temperatures. Adjuvants should not be added to this formulation. Do not exceed 10 ounces per acre unless under extremely cool conditions. The label does not allow this defoliant to be tank-mixed with Def. Prep or other forms of ethephon can be added to enhance defoliation and boll opening. The addition of 6 ounces of Ginstar per acre provides the equivalent of 0.05 pounds active ingredient per acre of thidiazuron.

Harvade 5F. Harvade has generally provided defoliation equivalent to that of the phosphate-type materials and is also not a strong inhibitor of terminal regrowth. Harvade has been reported to have better activity at low temperatures. Harvade provides excellent desiccation of mature morningglory in cotton, especially in mixtures with Prep. The addition of 1 pint per acre of crop oil is necessary for acceptable defoliation. Rainfall within six hours may reduce the effectiveness of Harvade.

Leafless. Leafless is a mixture of Dropp and Harvade. Research with Leafless is limited in North Carolina. The recommended rate of 10 to 12 ounces per acre provides 0.125 to 0.15 pounds of Dropp per acre and 6.4 to 7.7 ounces of Harvade per acre. Growers may want to add Harvade to bring the Harvade rate up to 8 ounces per acre along with Prep where morningglory desiccation is desired. The addition of 0.5 to 1 pint per acre of crop oil is necessary for acceptable defoliation.

Resource. Resource is a PPO-inhibitor herbicidal-type defoliant. Similar to Aim and ET, Resource should provide acceptable defoliation of mature leaves and desiccation of juvenile regrowth. The Resource label suggests the addition of 1 to 2 pints of COC or a nonionic surfactant in hotter weather.

BOLL-OPENING MATERIALS

Boll-opening materials are often used in combination with defoliation materials to increase the percentage of the crop harvested during first picking or possibly to eliminate the need for a second picking. Boll maturity is very important when using a boll-opening material. Lint micronaire and strength can be adversely affected if immature bolls are opened. In certain years cotton micronaire is improved by mixing higher micronaire cotton from the bottom of the cotton plant with lower micronaire cotton from the top. Picking capacity, the number of unopened bolls, and the cost of second picking determine whether boll opening is economical.

The application of boll-opening materials may be justified at any time during the harvest season, but they are often used on only part of the crop. For example, because of time constraints, the first third of the acreage to be harvested is often defoliated early when a large number of bolls have not opened. This portion of the crop may not benefit from boll-opening materials because the number of unopened bolls on these plants may justify a second picking even if a boll-opening material is used. In this case the farmer may want to avoid using boll openers and plan to use a second harvest on this portion of the crop. The second third of the crop to be harvested is most likely to benefit from boll-opening materials because it is less likely that a second picking will be justified. The use of a boll opener in this situation may well make the difference in the need to make a second picking. The final third of the crop to be harvested is usually the least likely portion of the crop to justify the application of a boll-opening material because most of the bolls there are more likely to have opened naturally. Also, the farmer has fewer time constraints at this point, and under cool temperatures Prep does not work as well (see Table 12-5 for boll-opening chemicals and instructions).

Prep 6, SuperBoll, Ethephon 6, other generics. Prep stimulates boll opening by increasing ethylene synthesis that normally occurs at boll opening. Mature bolls will usually open 10 to 14 days after application. However, boll opening is very rare and temperature-dependent, and best results are obtained when Prep is applied when night temperatures are above 60°F. Day temperatures between 65°F and 75°F will require twice the rate of Prep to produce the same speed and degree of boll opening as will be achieved if application is made when temperatures are 85°F to 95°F.

Deciding whether to use Prep for boll-opening purposes is often difficult. When making such a decision, it is helpful to consider that Prep plus defoliant mixtures usually give sufficient defoliation for harvest after 7 to 10 days. In addition, Prep usually doubles the number of green bolls that will open within 10 to 14 days after treatment. If harvest is delayed longer than 14 days after treatment, the advantage of Prep is often reduced.

Prep can be applied with other defoliants or in a second treatment after leaf drop has occurred. If the bolls you wish to open are under a canopy of leaves, it is better to apply the Prep after defoliation to ensure coverage of the bolls you want to open. Although Prep is not labeled as a defoliant, it does have some defoliant activity. Prep has provided satisfactory defoliation at a high rate of application (2 lb active ingredient/acre) under optimum conditions on well-matured cotton. The addition of Prep at lower rates with other defoliants has been reported to increase the degree of defoliation and hasten leaf drop under adverse conditions. Prep is compatible with Aim, Blizzard, Def, ET, Harvade, Dropp or FreeFall, Ginstar, and Resource, but it should never be mixed with sodium chlorate.

Paraquat (Gramoxone Max, Gramoxone Super Tres, Gramoxone Inteon). Paraquat has been used to open mature bolls by causing outside boll injury, which leads to drying of the carpal walls, boll cracking, and boll opening. Paraquat is generally used when weather conditions are cool and bolls are fully mature. Paraquat at lower rates (3 to 6 oz/acre) in addition to conventional defoliants may increase defoliation of juvenile growth and stimulate boll opening. Higher rates have been shown to actually cause bolls to "freeze" and not open under certain conditions; therefore, at least 80 percent of the bolls should be open before application. Development of immature bolls will be inhibited. Paraquat can also be used to "clean up" regrowth or otherwise missed leaves if harvest is delayed beyond 21 days after defoliation. However, growers can expect desiccation of these leaves, especially during warmer temperatures.

ADDITIVES

Accelerate (0.52 lb/gal of endothal concentrate) can be added to Def at 1.5 pints per acre to increase leaf drop by approximately 25 percent during the first few days of defoliant activity. This practice may allow an earlier application of Prep to open bolls where early harvest is important. Because total leaf drop after 7 to 10 days has generally not been improved with Accelerate, the use of the defoliant alone may be preferred if early harvest is not important.

According to labels, diesel oil can be added to Def to improve performance in cool weather or under drought-stress conditions. This effect has not been verified under North Carolina conditions. Be careful with diesel oil because of drift problems.

DESICCANTS

Sodium chlorate, Starfire. Desiccants are generally not used as harvest aids for cotton harvested with spindle-type pickers. If desiccation is necessary due to regrowth or weeds, it is best to apply a defoliant, wait until leaf drop occurs, and then apply the desiccant. Desiccants can kill the entire plant and burn immature bolls. Therefore, 90 percent of the crop should be open before applying a desiccant, and you should anticipate picking within seven days to avoid possible bark contamination (Table 12-6).

DEFOLIANT COMBINATIONS

The application of a single defoliant may be more economical than defoliant mixtures and can result in satisfactory defoliation. However, under less than desirable defoliation conditions, mixtures are likely to provide better results. Aim, Blizzard, Def, ET, Harvade, and Resource can be used in combination with Dropp/FreeFall or Prep. There is some indication that the activity of the PPO-inhibitor herbicidal defoliants (Aim, Blizzard, ET, and Resource) is so rapid that less thidiazuron makes it into the plant and may result in a shorter period of regrowth control when these materials are mixed with thidiazuron-containing defoliants. Defoliant selection should be based on whether juvenile growth needs to be defoliated, the need for regrowth control or boll opening, and the temperature at and following application. One defoliant may not provide all of the desired characteristics, so defoliant mixtures may be preferable. A list of the common defoliants and their characteristics is shown in Table 12-7.

DEFOLIATING RANK COTTON

Deciding how to defoliate rank cotton is always difficult. Producers often have to decide whether they will defoliate early in an effort to save the bottom crop (and lose the top crop) or wait for the top crop to develop before defoliating. Producers who wait for rank cotton to finish a top crop may very well lose much of their bottom crop to boll rot, especially if wet weather occurs and continues.

A common tendency when defoliating rank cotton is to use high rates of defoliants in an effort to cover and defoliate the entire plant. The Def label does suggest high rates for defoliating rank cotton. The problem with this approach is that the high rates of defoliants will tend to stick the leaves, especially on the top of the plant where most of the defoliant is intercepted. The safest approach is to apply the same rate of defoliants that you would if the cotton were not rank under the same crop and weather conditions, realizing that you may have to make a second application to defoliate the bottom portion of the crop.

You may consider bottom defoliation to decrease loss to boll rot in extremely rank cotton. Defoliate as high on the plant as possible until immature bolls are found. The idea is to remove enough leaves from the middles to allow air movement and light penetration. The lower labeled rates are usually used for bottom defoliation unless otherwise specified. Some research indicates that bottom defoliation can do more harm than good by mechanically injuring bolls and stems, resulting in increased chances for boll rot.

DEFOLIATING WEEDY COTTON

A weedy cotton field can present unique problems that standard defoliation practices won't handle. Weeds not only interfere with harvest options, but can stain lint and almost certainly increase the trash content of harvested bolls. For detailed information on defoliating weedy cotton, see the section on "Preharvest Herbicide Application" in chapter 10, "Weed Management in Cotton."

DEFOLIATION OF DROUGHT-STRESSED COTTON

Drought-stressed cotton often has thick and leathery leaves, and this condition may affect the plant's ability to take up the defoliant. However, growers are advised not to use high rates of defoliants or complex mixtures. Still, the uptake of thidiazuron products does appear to be reduced on drought-stressed cotton. Therefore, higher rates of thidiazuron may be needed on drought-stressed cotton. Mixtures of Def/Folex and thidiazuron have worked well in the past under these conditions. Recent research in other states suggests that the addition of either a silicone surfactant or crop oil plus ammonium sulfate increases thidiazuron uptake on drought-stressed cotton. However, these additives also increased the likelihood of leaf desiccation, and their general use is not recommended at this time in North Carolina.

REGROWTH CONTROL

Regrowth is most likely to be a problem on cotton that reaches cutout quickly, has a small or early maturing boll load, and has adequate heat and moisture and excess nitrogen. Controlling potential regrowth with thidiazuron is more effective than reapplying defoliants after regrowth has occurred. Reapplication of defoliants is permitted, but reapplication often provides less than desirable results because of poor coverage of small leaves and continuing emergence of new leaves. Desiccants can be used to eliminate unwanted regrowth. They should be applied at the earliest possible date to avoid new leaves reaching enough size to decrease grade.

DEFOLIANT APPLICATION

Defoliants should be applied in the late afternoon or early morning when humidity usually is high and winds are calm. Coverage is very important because each leaf that is to be removed must receive some defoliant. Defoliants can be successfully applied by airplane or ground machines.

Defoliation by aircraft. Successful defoliation by airplanes requires a uniform swath width and coverage of each leaf. The use of well-trained flagmen, permanent markers, or GPS will keep uniform swath widths and result in more uniform defoliation. Typical swath widths for popular agricultural aircraft are listed in Table 12-2.

Table 12-2. Typical Aircraft Swath Widths

Aircraft	Span	Wing (feet)	Swath Width (feet)
		5 GPA	10 GPA
Air Tractor	45 feet 5 inches	55 to 65	50 to 60
Ag Cat A	39 feet 1 inch	40 to 50	40 to 50
Ag Cat B	42 feet 3 inches	45 to 55	45 to 55
Cessna	42 feet 8 inches	45 to 55	45 to 55
Thrush 600	44 feet 5 inches	55 to 65	50 to 60

Thorough coverage by air requires a finished spray volume of 4 to 12 gallons per acre. Coverage depends on spray droplet size, atmospheric conditions, and the amount of foliage. In general, smaller spray droplets provide better coverage and canopy penetration but are more likely to drift in windy conditions or evaporate in high-temperature, low-humidity conditions. Larger spray droplets reduce drift and evaporation but provide less coverage and canopy penetration. Medium-sized droplets by disk and core-type hollow cone nozzles with number 8, 10, and 12 disks or number 46 and 56 cores are recommended. These nozzles should be turned down and 45 degrees back on 100- to 120-mph aircraft and straight back on 120-mph to 150-mph aircraft. Removing nozzles from at least the outer 20 percent of the aircraft wing is recommended to reduce drift. Higher finished spray volumes improve coverage and give more thorough defoliation, especially on large plants with lush foliage.

Defoliation by ground machines. Research indicates that cone-type nozzles are superior to flat fan or flood nozzles for foliar coverage. Two equally spaced hollow cone nozzles per row should give adequate coverage. Spray pressure, ground speed, and nozzles should be matched to apply a finished rate of 15 to 20 gallons per acre.

FROST DEFOLIATION

Some producers like to wait and let frost defoliate cotton. This delay is generally not desirable because of the loss of quality and yield that can occur while waiting for a frost. A light frost can defoliate cotton fairly well, but a hard frost (below about 28° F) can stick leaves and rot bolls. Less mature leaves and bolls are more likely to be negatively affected by frost because of their higher water content. It is common for a frost to take off the top leaves, leaving enough bottom leaves to require chemical defoliation following the frost.

Producers should wait several days following a frost to make defoliation decisions. Boll-opening materials usually do not work following a frost that was strong enough to turn bolls brown. If you can thump leaves and they fall off a week following a frost, those leaves will probably drop off. If the leaves do not drop, they are stuck. See Table 12-5 for defoliants.

ROTATIONAL CROPS RESTRICTIONS

Table 12-3. Label Restrictions for Planting Small Grains Following Application as a Harvest Aid in Cotton

Material	Recrop Interval Following Application for Planting Small Grains
Def/Folex	None
Thidiazuron	14 days
Harvade	6 months
Ginstar	1 month
Leafless	6 months
Aim	None
ET	None
Blizzard	None
Resource	30 days
Prep/SuperBoll, others	30 days
CottonQuik/FirstPick	30 days
Finish	1 month
Glyphosate	None
Sodium Chlorate	None
Paraquat	None

With increased interest in double-cropping wheat following cotton, some consideration should be given to label restrictions of harvest aides for rotational crops. Table 12-3 summarizes harvest aid label restrictions for planting wheat following cotton.

DEFOLIATION AND BOLL-OPENING SCENARIOS

The following are some defoliation situations typically encountered in North Carolina. Defoliation rates and materials are suggested as guides to use under different weather situations. Other combinations may work equally well, but these are some more commonly used combinations.

Ginstar can be used as a stand-alone treatment under all the scenarios presented below. Ginstar should not be used in combination with other herbicidal defoliants unless the rates of one or both are reduced. Ginstar can be used in combination with ethephon-containing, boll-opening materials. Rates can be reduced in combination with Finish or CottonQuik. The new defoliants Aim and ET could be substituted for Def in the situations listed below. Their activity is not very temperature-dependent, so the rates would tend to stay the same for the scenarios listed below.

Drought Stress, High Temperatures (90s °F), Lows (70s °F)

Drought-stressed cotton leaves have thickened cuticles that often reduce penetration of defoliant materials. High temperatures usually will enhance leaf burn and can increase leaf sticking. Under these conditions, combinations of three or more materials often result in leaf sticking. Regrowth is usually a problem when rainfall occurs. Lower rates of the herbicidal defoliants should be used to reduce leaf burn, while higher rates of defoliants controlling regrowth may be needed because of reduced penetration into the cotton plant. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation.

1. Def (1.3 pt) (defoliation)
2. Dropp or FreeFall (0.075 to 0.1. lb ai) (defoliation or regrowth control)
3. Def (0.5 to 1 pt) + Dropp or FreeFall (0.05 to 0.1 lb ai) (defoliation or regrowth)
4. Dropp or FreeFall (0.05 to 0.1 lb ai) + Prep (5.33 oz) (defoliation or regrowth control)
5. Dropp or FreeFall (0.05 to 0.1 lb ai) + Prep (1.33 to 2 pt) (defoliation or regrowth/boll opening)
6. Def (0.1 to 1.3 pt) + Prep (1.33 to 2 pt) (defoliation or boll opening)
7. Sodium chlorate (3 lb active ingredient) (defoliation, less effective)
8. Finish (1.3 to 2 pt) (defoliation and boll opening) (Add Dropp or FreeFall [0.05 to 0.1 lb ai] or Def [0.5 pt] if rank growth or regrowth is present.)

9. Aim, Blizzard, ET or Resource (recommended rates) + Dropp or FreeFall (0.1 ai to 0.15 lb ai) (defoliation or regrowth)

10. Aim, Blizzard, ET or Resource (recommended rates) + Prep (1.33 to 2 pt) (defoliation or boll opening)

11. CottonQuik/FirstPick (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (0.5 pt)

Normal Cutout, High Temperatures (90s °F), Lows (70s °F)

Cotton with a good boll load, normal cutout, and warm day and night temperatures generally defoliates well. Regrowth is often a problem, depending on boll load, soil moisture, and night temperatures after defoliation. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates. A nonionic surfactant should be used in place of crop oil in high temperatures to reduce desiccation.

1. Def (0.75 to 1.0 pt) (defoliation)

2. Dropp or FreeFall (0.05. to 0.1 lb ai) + Def (0.5 to 1.0 pt) (defoliation or regrowth control)

3. Dropp or FreeFall (0.05 to 0.1 lb ai) + Prep (5.33 oz) (defoliation or regrowth control)

4. Dropp or FreeFall (0.05 to 0.1 lb ai) + Def (0.25 to 0.50 pt) +Prep (1.33 to 2 pt) (defoliation or regrowth control/boll opening)

5. Def (0.75 to 1.25 pt) + Prep (1.33 to 2 pt) (defoliation and boll opening)

6. Sodium chlorate (3 lb active ingredient) (defoliation, less effective)

7. Aim, Blizzard, ET or Resource (recommended rates) + Dropp or FreeFall (0.05 to 0.1 lb ai) (defoliation or regrowth)

8. Aim, Blizzard, ET or Resource (recommended rates) + Prep (1.33 to 2 pt) (defoliation or boll opening) (Finish or FirstPick can be substituted for Prep, but both are used at different rates.)

9. Finish (1.3 to 2 pt) (defoliation and boll opening) (Add Dropp or FreeFall [0.05 to 0.1 lb ai] or Def [0.5 pt] if rank growth or regrowth is present.)

10. CottonQuik/FirstPick (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (0.5 pt)

11. Ginstar (4 to 6 oz) (defoliation or regrowth control) (Add boll opener if needed.)

Normal Cutout, High Temperatures (80s °F), Lows (60s °F)

Cotton with a good boll load, normal cutout, and warm day and night temperatures generally defoliates well. Good coverage is important, and higher rates of herbicidal defoliant can generally be used. Regrowth may or may not be a problem, depending on boll load and night temperatures after defoliation. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates.

1. Def (1 to 1.5 pt) (defoliation)
2. Dropp or FreeFall (0.125 to 0.2 lb) + Def (1 pt) (defoliation or regrowth)
3. Dropp or FreeFall (0.125 to 0.2 lb) + Prep (5.33 oz) (defoliation enhancement)
4. Dropp or FreeFall (0.1 to 0.125 lb) + Def (0.25 to 0.50 pt) + Prep (1.33 to 2 pt) (defoliation or regrowth/boll opening)
5. Def (1 to 1.5 pt) + Prep (1.33 to 2 pt) (defoliation and boll opening)
6. Harvade (0.5 pt) + crop oil (1 pt) (defoliation)
7. Harvade (0.5 pt) + crop oil (1 pt) + Prep (1.33 pt) (defoliation or boll opening or weed desiccation)
8. Sodium chlorate (3.5 to 4 lb active ingredient) (defoliation or weed desiccation) (less effective)
9. Aim, Blizzard, ET, or Resource (recommended rates) + Dropp or FreeFall (0.125 to 0.20 lb) (defoliation or regrowth)
10. Aim, Blizzard, ET, or Resource (recommended rates) + Prep (1.33 pt) (defoliation or boll opening) (Finish or FirstPick can be substituted for Prep, but both are used at different rates.)
11. Aim, Blizzard, ET, or Resource (recommended rates) + Def (1 to 1.25 pt) (defoliation)
12. Finish (1.3 to 1.5 pt) (defoliation and boll opening) (Add Dropp or FreeFall [0.05 to 0.1 lb] or Def [0.5 pt] if rank growth or regrowth is present.)
13. CottonQuik (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (0.5 pt) (defoliation and boll opening)
14. Finish (1.3 to 1.5 pt) or CottonQuik (2 qt) + Harvade (0.5 pt) + crop oil (1 pt)(defoliation, boll opening, and weed desiccation)
15. Ginstar (6 to 8 oz) (defoliation or regrowth control) (Add boll opener if needed.)

Late Season, High Temperatures (60s to 70s °F), Lows (50s °F)

For best results, defoliation should be delayed until warmer weather occurs, if possible. Def can be replaced with ET or Aim in any of the following mixtures at recommended rates.

1. Def (1.5 to 2.5 pt) (defoliation)
2. Dropp or FreeFall 50 WP (0.1 to 0.125 lb) + Def (2 pt) (defoliation or regrowth)
3. Harvade (0.5 pt) + crop oil (1 pt) (defoliation)
4. Harvade (0.5 pt) + crop oil (1 pt) + Prep (1.33 to 2 pt) (defoliation or boll opening at higher rates of Prep or weed desiccation)
5. Harvade (0.5 pt) + crop oil (1 pt) + Def (1 pt) (defoliation)
6. Sodium chlorate (4 lb active ingredient) (defoliation, less effective/weed desiccation)
7. Aim, Blizzard, ET, or Resource (recommended rates) + Dropp or FreeFall (0.125 to 0.2 lb) (defoliation or regrowth)
8. Aim, Blizzard, ET, or Resource (recommended rates) + Prep (1.33 to 2 pt) (defoliation/boll opening at higher Prep rates)
9. Aim, Blizzard, ET, or Resource (recommended rates) + Harvade (0.5 pt) + crop oil (1 pt) (defoliation)
10. Aim, Blizzard, ET, or Resource (recommended rates) + Def (1 to 1.5 pt) (defoliation)
11. Finish (1.5 to 2 pt) (defoliation and boll opening) (Add thidiazuronl [0.05 to 0.1 lb] or Def [1 to 1.5 pt] if rank growth or regrowth is present.)
12. CottonQuik (2 qt) + Dropp or FreeFall (0.05 to 0.1 lb) or Def (1 to 1.5 pt) (defoliation and boll opening)
13. Finish (1.3 to 2 pt) or CottonQuik (2 qt) + Harvade (0.5 pt) + crop oil (1 pt)(defoliation, boll opening, and weed desiccation)
14. Ginstar (8 to 10 oz) (defoliation or regrowth control) (Add boll opener if needed.)

Table 12-4. Harvest Aid Performance

Material	Estimated minimum temperature	Expected activity			
		Mature leaves	Juvenile growth	Regrowth prevention	Boll opening
Def/Folex	60°F	Excellent	Fair	Poor	None
Thidiazuron	65°F	Excellent	Excellent	Excellent	None
Harvade	55°F	Excellent	Fair	Poor	None
Ginstar	60°F	Excellent	Excellent	Excellent	None
Aim	55°F	Excellent	Excellent	Poor	None
ET	55°F	Excellent	Excellent	Poor	None
Resource	55°F	Excellent	Excellent	Poor	None
Blizzard	55°F	Excellent	Excellent	Poor	None
Prep/SuperBoll, others	60°F	Fair	Poor	Poor	Excellent
Finish	60°F	Excellent	Poor	Fair	Excellent
CottonQuik/FirstPick	60°F	Excellent	Poor	Poor to Fair	Excellent
Glyphosate	55°F	Fair	Fair	Excellent	None
Sodium Chlorate	55°F	Fair	Fair	Poor	None
Paraquat	55°F	Desiccation	Excellent	Poor	Fair

Table 12-5. Boll Opening Rates

It may be desirable to accelerate the opening of mature cotton bolls for earlier harvest or for a once-over harvest operation. Prep (ethephon) has been shown to accelerate the opening of bolls and enhance defoliation. Immature bolls also will be affected and, depending on the stage of maturity, fiber may be immature, seed quality lower, and yield reduced. Application should not be made until enough mature, unopened bolls have developed to produce the desired yield of cotton. Cool, damp conditions occurring within 48 hours before or after treatment may severely inhibit the effectiveness of Prep.

Trade Name (product/a)	Common Name (rate a.i./a)	Application Instructions
Prep 6 (1.33–2.66 pt)	ethephon (1–2 lb)	Apply in 5 to 50 gal/acre of water when 40 to 60 percent of the bolls are open and when there are sufficient mature, unopened bolls to produce the desired yield. Prep can be used four to seven days before application of defoliants as a preconditioning agent, tank-mixed with defoliants, or applied after defoliation. Rank cotton will often require defoliation before Prep application in order to obtain good spray coverage of bolls. DO NOT harvest cotton sooner than seven days after Prep application. DO NOT mix Prep with sodium chlorate products because toxic chlorine gas fumes will be produced.
Finish (1.3–1.5 pt)	ethephon (1–1.5 lb) + Cyclanilide (0.5–0.75 lb)	
CottonQuik FirstPick (2 qt)	ethephon (1.14 lb) + AMADS (7.3 lb)	

Table 12-6. Desiccant Rates

Desiccants primarily dry plant tissue. These chemicals usually act so rapidly that leaves are killed and stick to the stalk, and defoliation does not occur. Desiccants are generally recommended in areas where cotton is harvested by strippers. In North Carolina, desiccants should be used only as a last resort to eliminate second growth, especially on ultra narrow row stripper cotton.

Trade Name	**Common Name**	**Application Instructions**
(product/a)	(rate a.i./a)	For use as a desiccant, apply when 80 percent or more of the bolls are open and the remaining bolls to be harvested are mature. DO NOT apply within three days before harvest. Paraquat may also be applied at 3 to 6 oz/acre with defoliants to hasten boll opening. Paraquat is a Restricted Use pesticide.
Paraquat (various brand names) (1.5–2.5 pt)	paraquat (0.25–0.5 lb)	

Table 12-7. Defoliants

The chemicals below are labeled for use as defoliants. They will defoliate cotton but will not kill the stalk under normal usage. Some regrowth will occur with all of these products.

Trade Name (products/a)	**Common Name**	**Application Instructions**
Accelerate 0.52 lb/gal (1–1.5 pt.)	endothal	Accelerate may be added to Def at 1.5 pt/acre to speed leaf drop by approximately 25% during the first few days of defoliant activity. The rate of leaf drop after 7 to 10 days has generally not been improved with Accelerate. Always add Accelerate to organic phosphates (Def) previously tank-mixed with water.
Aim 40 DF (0.66–1 oz)	carfentrazone-ethyl	Aim can be used in place of other herbicidal defoliants. Growers should be careful about using Aim in conditions that are subject to causing desiccation until more research is conducted. Aim does appear to desiccate morning glory. The label states that Aim should be applied with a 1% by volume crop oil.
Blizzard 0.91 lb/gal (0.5–0.66 fl. oz.)	Fluthiacetmethyl	Blizzard is a PPO-inhibitor herbicidal-type defoliant. Experience with Blizzard in North Carolina has been limited. Blizzard can be tankmixed with ethephon-based products. Similar to other PPO-inhibitor defoliants, Blizzard should be very useful in desiccating juvenile foliage and as a second application prior to harvest. A crop oil concentrate or surfactant should be added to tank mixes containing Blizzard according to label directions.
sodium chlorate (several name brands) Read label for rates.	sodium chlorate with fire suppressant	Apply to mature cotton plants after the youngest bolls expected to make cotton are at least 30 days old. DO NOT apply later than seven days before harvest. With ground equipment, use 10 to 20 gal of spray solution per acre, and by air use 5 to 10 gal/acre.
CottonQuik/ FirstPick (1.7–3 qt)	ethephon + synergist	Use higher rates only during cool weather. Limited experience suggests that CottonQuik will provide defoliation of mature leaves and has boll-opening activity. CottonQuik can be tank-mixed with Dropp or FreeFall if regrowth is expected. In adverse conditions, with rank growth or juvenile growth, a tank mixture with another defoliant will improve defoliation.
Def 6 (1–2 pt)	tribufos	Def should be applied when 50% or more of the bolls are open and 7 to 10 days before anticipated picking. Use the low rate when the crop is mature and the weather is warm. When plants are still green and actively growing, the temperature is cool, or the weather is dry, use higher rates or a tank mix with another defoliant. A spray mix of 5 to 25 gal/acre should be applied.

continued

Table 12-7. Defoliants (continued)

The chemicals below are labeled for use as defoliants. They will defoliate cotton but will not kill the stalk under normal usage. Some regrowth will occur with all of these products.

Trade Name (products/a)	Common Name	Application Instructions
Dropp or FreeFall (0.2–0.4 lb)	thidiazuron	Dropp or FreeFall should be applied to plants ONLY when 60 to 70% of the bolls are open. Apply in 10 to 25 gal of water per acre by ground equipment and in 2 to 10 gal/acre by air. Use higher rates during periods of low temperatures. Apply at least five days before picking. May be tank-mixed with Def or Prep. Dropp or FreeFall rates as low as 0.1 lb of product per acre may be used in tank mixes. Spray tanks should be cleaned immediately after using Dropp or FreeFall. A nonionic surfactant or compatibility agent is recommended when using tank mixes of Dropp or FreeFall plus Def to facilitate cleanup. See label for more information.
ET (1.5–2 oz).	pyraflufen ethyl	ET should be applied in 20–30 gpa by ground (1.5 or at least 5 gpa if applied by air). ET can be applied using one or two applications, but do not exceed a total of 5.5 fl oz of product per acre. Crop oil at a rate of 1% should be used with ET and defoliant mixtures with ET. Do not use crop oil when mixed with CottonQuik. No surfactant or a nonionic surfactant should be used in mixtures with CottonQuik. A 2% rate of crop oil should be used if applied by air. There is little experience in North Carolina with ET applications in high temperature. Some states recommend that crop oil rates be reduced or eliminated in high temperatures to avoid desiccation.
Ginstar 1.5 EC (6.5–10 oz)	thidazuron + diuron	Do not exceed 10 oz/acre unless under extremely cool conditions. Ginstar is similar to Dropp Ultra but contains an enhancing agent, and thereforre an adjuvant should be used.
Finish 6 4 Pro 6 EC (1.3–2.7 pt.)	ethephon +cyclanalide	Use higher rates in cool weather. Finish is a defoliant and boll opener. Finish also provides some regrowth control. Terminal regrowth control is stronger than basal regrowth control. Finish will provide acceptable regrowth control in many situations. In situations where extended regrowth control is needed (in the 20- to 28-day range), Dropp/FreeFall would provide more acceptable regrowth control. Finish performance may benefit from the addition of a low rate of a standard defoliant in situations where cotton is actively growing with juvenile growth, especially under cooler conditions.
Harvade-5F (0.5 pt.) + Crop oil concentrate (1 pt)	dimethipin + crop oil concentrate	Harvade is a harvest growth regulant that affects certain plant processes that lead to defoliation. Complete coverage is essential. Harvade should be applied to mature cotton plants when 70% or more bolls are open. A mixture of Harvade plus 1 1/3 pt of Prep has been effective in drying annual morning glory vines entangling cotton.
Resource 0.86 lb gal (4–6 oz)	Flumiclorac-pentyl	Under ideal defoliation conditions (warm sunny days), add a NIS at 1 qt per 100 gal of spray solution. Under dry or cool weather, a methylated seed oil (MSO) or organosilcone adjuvant may be used. Apply in a minimum of 10 gal per acre for ground applications and a minimum of 5 gal per acre for aerial applications. Do not use flood jet or air induction nozzles. Resource can be tank-mixed with other products if boll opening or regrowth control is desired. Resource only needs a 1-hr rain-free period. Preharvest interval (PHI) is seven days.

13. COTTON PRODUCTION WITH CONSERVATION TILLAGE

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COTTON AND SOIL CONSERVATION

Conventionally tilled cotton on sloping, erodible land has a well-deserved reputation for contributing to soil erosion. Cotton grows slowly during early summer and provides little crop protection from raindrop impact and soil erosion. Cultivation enhances the potential for soil erosion. Cotton also provides relatively little residue to return to the soil or to leave on the surface to protect it from erosion during the winter.

Conservation compliance was introduced in the 1985 Farm Bill and continues to be reinforced in the 2014 Farm Bill. Fundamental to these bills were efforts to reduce soil loss associated with cultivation of annual crops on highly erodible land (HEL), which is defined according to a formula that considers normal rainfall patterns, the gradient and length of slopes, and the inherent erodibility of the specific soil. To be eligible for program benefits, including "market transition payments" and conservation cost share, growers were required to have and follow an approved conservation farm plan if highly erodible land was involved. The 2014 Farm Bill maintains this focus on conservation. Provisions related to conservation tillage include cost-share opportunities for long-term no-till through the Environmental Quality Incentives Program (EQIP) and perhaps other opportunities through new conservation programs. Consult with local program offices for details. Producers need to consider that long-term no-till currently requires a five-year time commitment and that the cropping system must provide 80 percent ground cover. This practice may require careful cover crop management to insure optimum stands and sufficient residue.

Conservation tillage is often the agreed-upon and most effective approach to protect against soil erosion and to meet conservation compliance requirements on highly erodible land. No-tillage planting into a residue cover offers the additional benefits of conserving moisture on drought-prone soils and protecting young cotton seedlings from sandblasting. Also, a no-tillage system can save time during the planting season, allowing growers to plant cotton and other crops closer to the optimum planting date.

Research results, as well as the experience of growers in North Carolina and other states, show that cotton can grow successfully under conservation tillage systems. However, in these methods of cotton production, which are sometimes collectively referred to as "no-till cotton," success requires planning and a high level of management. Growers are encouraged to start with a small acreage of "no-till cotton," seeking to resolve the practical challenges of this system within their own operations. Growers who adopt such a system on small acreages are encouraged to evaluate this system in multiple environments (both wet and dry years) and scout their crop to look for signs of root obstruction before adopting a widespread no-till system. Many sources of information exist, including the successful growers in many counties where thousands of acres of conservation-tilled cotton are now being grown.

COVER CROP SELECTION AND MANAGEMENT

To meet conservation-tillage requirements in North Carolina, surface residues must provide at least 30 percent ground cover after planting. A cover crop will be required in most situations. Residues from a good previous corn crop may provide sufficient cover; residues from soybeans, peanuts, tobacco, or cotton will not be adequate. **If relying on residues from a previous crop** to provide sufficient cover, do not perform any tillage operations between harvest of the previous crop and planting of the cotton.

Cover crops are often recognized for their long-term benefits, such as soil erosion reduction and enhanced nutrient cycling; however, there are also short-term benefits that can be gained through cover crop use. Some of the most important short-term benefits include weed suppression and enhanced soil moisture availability to the cotton crop.

Potential cover crops include small grains (most commonly wheat or cereal rye) and winter legumes (winter pea, hairy vetch, or crimson clover). Nitrogen production is the primary advantage of a legume cover crop. Hairy vetch or crimson clover can provide nitrogen to cotton equivalent to 50 to 70 or more pounds of fertilizer N per acre. This nitrogen production can be difficult to accurately predict, and N release from a legume cover crop depends on environmental conditions, complicating decision-making on the amount and timing of the nitrogen release provided to the following cotton crop. Thus, it may be difficult to decide how much, if any, additional fertilizer nitrogen to apply. Excess nitrogen can lead to substantial problems for cotton producers. But in most circumstances, legume N release following termination is rapid and therefore would not be problematic for late-season N management (see the discussion of nitrogen fertilization in chapter 7, "Fertilization"). Legume cover crop residues decompose quickly, and therefore have limited value as a mulch targeted at weed control and soil moisture conservation during the cotton production season.

Small-grain cover crops have different advantages than can be achieved with a monoculture legume cover crop. The seed of a small grain cover crop is more economical, and small grains are easier to establish and to kill than legumes. Small grains can be successfully established later in the fall than can legumes, allowing more time to harvest cotton and other crops before seeding the cover crop. Small grains typically provide more protection from soil erosion during the fall and winter months than do legumes. A small grain cover crop decomposes more slowly and produces more biomass than a legume cover crop, and therefore is more beneficial as a mulch for weed suppression and soil moisture conservation in the following cotton crop. In addition, concern about nitrogen leaching and protection of water quality is increasing. Small grain cover crops also have the benefit of "scavenging" leftover nitrogen from the previous cash crop season, which can reduce excess N movement into groundwater.

Cereal rye is a popular cover crop choice in the no-till system for its ability to produce high cover crop biomass, well in excess of what can typically be achieved with wheat. High cover crop biomass production results in a more persistent cover crop mulch that can prolong the in-season benefits of weed suppression and soil moisture conservation. While high biomass production from cereal rye is advantageous for weed suppression and soil moisture conservation, it can intensify problems at planting compared to planting into a wheat cover crop where lower residue levels are typically encountered. Problems penetrating through the cover crop mulch at planting to get good cotton seed-to-soil contact can be overcome through planter modifications allowing for residue movement from the crop-row. The management of a cereal rye cover crop prior to a cotton crop will have a great impact on the benefits achieved during the following cotton season. To maximize cover crop biomass, cereal rye should be planted early at high seeding rates. If cereal rye establishment must be delayed into late fall due to weather or other management events, growers can consider fertilizing their cereal rye in an attempt to increase biomass. Cereal rye desiccation via roller-crimping or herbicide burndown should occur in close proximity to cotton planting to ensure maximal cover crop biomass is achieved prior to cotton establishment. Newly developed specialized equipment may be needed to plant cotton in a high residue system, and such equipment is now commercially available.

Cover crop mixtures of small grains and legumes can be used to maximize the benefits that can be obtained from both species. Recent research in North Carolina suggests that a crimson clover and cereal rye cover crop mixture worked well prior to cotton; planting into this cover crop mixture was not problematic for cotton establishment, and the benefits of early season weed suppression and soil moisture conservation were observed.

Under continuous cotton production, cover crop species, establishment method, and termination timing are critical to the success of a winter legume as a nitrogen source. Species selection should be based on suitability to soil characteristics to ensure ease of establishment and high biomass level. For example, vetch tends to do well in heavier soils, whereas crimson clover performs better in sandy soils. Each grower must determine which species performs best on their soils. Cover crop establishment is best achieved when the soils are warm and moist, before cotton harvest, to promote legume germination and seedling growth. Research results indicate that overseeding winter legumes approximately 14 days prior to defoliation provides adequate stands of the winter legumes, high cover crop biomass at planting, and sufficient soil N. Legume germination may be complicated by defoliant choice. Cotton defoliants containing thiadiazuron have been shown to reduce legume germination and seedling growth in greenhouse experiments, but these defoliants had little to no effect in field experiments when legumes were overseeded 14 days prior to defoliation. Soil moisture preservation must always be accounted for when determining when to terminate your cover crop. The termination date should be adjusted to assure adequate soil moisture to promote cotton germination and early season growth. Cover crop termination 10 days prior to planting proved to be optimal timing for high cover crop biomass, soil moisture preservation, adequate soil N, and high lint yield.

Soil samples should be taken in early fall to allow time for analysis before seeding the cover crop. Suggested lime and phosphorus (unless the required P_2O_5 can be applied in a starter band application) should be broadcast and worked into the soil during seedbed preparation for the cover crop. Where a strict no-till system is used, lime, phosphorus, and potassium are not incorporated into the soil. Because these amendments move very slowly into the soil, they can become concentrated in the surface soil and deficient lower in the root zone. It is imperative that adequate levels of these amendments be applied to the soil and incorporated throughout the root zone before initiating a strict no-till system. Once adequate fertility and pH are achieved throughout the root zone, decrease the soil sampling depth from 8 to 4 inches on no-till fields.

Except for sandy, less productive soils, nitrogen fertilization of the cover crop is generally unnecessary and may promote excessive vegetative growth of the cover crop. In general, it also would make the small-grain cover less effective in removing soil nitrogen for the benefit of water quality protection. Fall tillage to prepare a cover crop seedbed also will help to avoid problems with horseweed and cutleaf evening primrose and will provide some suppression of perennial weeds, and can enhance cover crop biomass production.

PLANTING METHODS

During the last decade or so, we have seen increasing acreages of North Carolina cotton being grown with some form of conservation tillage. Although often referred to simply as "no-till cotton," several approaches are being used successfully. Some of these are:

1. **In-row subsoiling** at depths of 10 to 16 inches. This practice is really a form of strip tillage in that considerable soil preparation in the row zone is provided by the coulter, ripper, and other components of the unit that closes the ripper slit in the soil. Planters may be attached to the ripper unit for one-pass planting, or the strip tillage can be done in a separate pass some time before planting. Due to the tractor power required for a six-row or eight-row ripper unit, it may be necessary to do the planting in a separate pass.

2. Strip tillage in the row zone **without subsoiling**. This tillage may be done with an arrangement of coulters or spider gangs to till a row zone of about 8 to 12 inches in width. This practice works especially well when beds have been made the preceding fall or in early spring.

Strip-till equipment currently on the market generally includes combinations of coulters, rolling baskets, spider gangs, rubber firming wheels, and/or other devices. These serve to do some soil conditioning in the row zone and to close the slits left by the subsoilers or other types of shanks that offer deep tillage and are included with these strip-till machines. However, these row-zone tillage devices also may allow shallow soil mixing, especially when rolling baskets or spider gangs are included and are properly adjusted to accomplish that function.

3. No-till planting using a row planter only. This practice commonly includes a fluted, bubble, or ripple coulter mounted ahead of the planter. The width of the tillage is narrow, typically from 3/8 inch to 1½ inches, and is determined by the lateral pushing and fracturing of the soil by the coulter flutes (waves) or by the "bubbles" on that coulter type.

BEDDING AND RIPPER/BEDDING

In general, a cotton crop is susceptible to extended periods of both wet and cool soils. Bedding provides some protection from both, especially early in the growing season. For this reason, planting cotton on raised beds is a strong preference of many conventional-tillage cotton growers. If growers decide to change to conservation tillage and wish also to plant on some degree of a bed, then special efforts are needed. Achieving **conservation-tilled cotton with bedding** requires either fall bedding or re-using the remnant bed from the previous crop. Further, **when conservation compliance is required,** or where growers simply wish to gain benefits from conservation tillage, establishment of a cover crop on these beds is generally necessary to meet the residue cover required for acceptance as conservation tillage (a minimum of 30 percent of the soil surface under residue cover after planting of the summer crop).

This establishment of a cover crop could be done by fall bedding or ripper/bedding, with a small-grain cover crop being planted at the same time or shortly after the fall bedding. This practice is successful where cotton follows tobacco, peanuts, or corn because these crops allow ample time after harvest for some root decomposition, fall tillage, and cover crop establishment. However, following cotton, fall bedding works best if the cotton stalks are uprooted by rigorous disking or by some form of stalk pulling.

In a continuous cotton operation, fall bedding (especially ripper/bedding) is often very difficult when the harvest is completed in late November or even in December. In general, we do not recommend using an in-row subsoiling device, especially a conventional ripper/bedder, running directly into the old (nontilled) cotton row positions in the fall or early winter. This practice usually presents frequent problems with roots wrapping and clogging on the rippers. Running rippers in mid-row positions would work better, but it is difficult to maintain the alignment to do this well.

Where cotton follows cotton, and where subsoiling is desired because of sandy soils and pan layers, useful alternatives are the **"Paratill"** of the Tye Company and Bigham Brothers Inc. and a similar tool known as the TerraMax of Worksaver Inc. These tools feature a deep loosening point that is carried in the soil on an angled shank ("leg"). A leading coulter cuts the residue in the path of the shank. These tools generally run without problems of root clogging, mainly because the shank enters the soil from the side of the old row. Again, careful driving to maintain tillage and row alignment is important. The effectiveness of such equipment in shattering pan layers is without question. The shatter zone is somewhat larger than that of conventional rippers. However, this equipment may require greater pulling power per shank than conventional in-row subsoilers, and there is significant expense involved in replacing the worn points on the legs of the Paratill units.

Establishment of a good cover crop in a continuous cotton system requires an emphasis on achieving timeliness. Wet weather and other time conflicts make it a challenge to establish the cover crop properly and sufficiently early to achieve the desired residue and cover benefits. Where new beds are made in the fall, some shaping or leveling of the bed is desirable before seeding the cover crop.

Because of these difficulties and the costs of achieving both bedding and good cover-crop establishment, growers are often forced to give up beds in conservation-tilled cotton. This circumstance is especially true where cotton follows cotton. Nevertheless, in typical growing seasons (when drought stress is more serious than wetness), the moisture-conserving benefits of good residue cover under conservation tillage more often than not offset the lack of benefit from bedding.

Where the following cotton crop will be flat-planted, consider using a no-till drill to plant into standing cotton stalks after the cotton is picked. This practice will save time and help to get the cover crop seeded earlier. Stalks can then be mowed afterward. These drills perform quite well if seeding depth is adjusted to compensate for ground-level differences of the beds and valleys. One exception is the case of drills having an exposed drive chain, where cotton stalks can cause the chain to run off. A homemade chain shield could be added to prevent this run-off. This approach to seeding cover crops works best on flat-planted cotton residue, or where existing beds are being used for cotton the following year. On the other hand, simply broadcasting small grain seed on freshly bedded or bed-shaped land may give adequate cover-crop establishment. Where cotton is to follow peanuts, growers often have had good cover-crop success by distributing wheat or cereal rye seed just ahead of peanut digging, assuming that the peanut "hay" is not being removed for animal feed.

Where cotton is flat-planted, rows can be offset by about 2 to 6 inches from one year to the next, thus possibly avoiding some no-till planting difficulties caused by previous crop stalks located in the exact new row position. Without beds, planting of the cover crop in the fall is easier and quicker. For flat-planted cotton, in-row subsoiling done a few inches beside the old row, either in the fall or spring, is also less problematic.

With several years of conservation tillage, there is some indication that soil porosity and drainage behavior may improve. Except in soils with naturally high water tables, this improvement could even reduce the need for bedding to protect from the risks of soil wetness. These aspects of soil management with long-term conservation tillage are now receiving the attention of farmers and researchers.

FALL RIPPING AND CARRYOVER EFFECTS OF SUBSOILING

To spread the work load and make efficient use of available tractor power, growers ask whether fall ripping is as effective as ripping at planting time. We recently completed a three-year study of "carryover" ripper effectiveness, including one site in a strong pan-layer-prone soil (Conetoe loamy sand). **Fall ripper/bedding was fully as effective for cotton yield as was ripping in the spring.** We followed the fall ripper/bedding by a wheat cover crop, strip-killed the cover crop over the intended row zone, and then no-till-planted cotton without ripping. In that study we also attempted to use the ripped zone for a full second and third year of straight no-till planting over the previous ripped row. **We lost about half of the ripper benefit in the first carryover year and about 80 percent of the benefit in the second carryover year.** These studies were done in a cotton/corn rotation.

STRIP TILLAGE VERSUS NO-TILLAGE

Strip tillage simply means some form of tillage in the row zone, generally 8 to 16 inches wide. This tillage may be only 1 to a few inches deep or, in the case of in-row subsoiling, typically 10 to 16 inches deep. This is being done with rubber wheels, aggressive coulters, rolling tines, shallow shanks, or shovels (any of these must provide appropriate closure and soil-conditioning devices). Also, it may involve deeper chisel or ripper shanks (with appropriate soil closure devices).

After some 20 replicated studies of cotton comparing conventional tillage, fluted coulters (1-inch flutes), shallow strip tillage, and in-row subsoiling, we have found that in at least three-quarters of the studies there were somewhat lower lint yields from use of the fluted coulter alone. The reasons for these lower yields from simple coulter-no-till appear to vary according to soil properties and residue conditions. In most cases there are somewhat more stand skips where no row-zone tillage is done (such as by a ripper, coulters, or rolling tines). This situation is especially likely where residue is tough or heavy (rather mature cereal rye or wheat) and the soil is soft. Under these conditions, "hair pinning" often results in inadequate closure of the seed furrow and poor seed-soil contact.

Prior killing of a narrow strip in the row-zone (**strip-killing**) has shown some benefit for cotton-stand establishment in cases of fairly heavy cereal rye or wheat residue at planting time. In other cases, soil properties influence the cotton response to some row-zone tillage. In the more sandy, pan-layer-prone soils, subsoiling generally provided the superior yield. In eroded, poor-tilth, crust-prone, coastal plain fields, shallow strip tillage was superior. In wet seasons or wet-natured soils, conventional tillage may be favored. In any case, where satisfactory cotton stand and good weed control are achieved, one of these forms of conservation-tilled cotton has generally given similar yields to conventional tillage.

CONCEPTS OF STRIP TILLAGE VERSUS METHODS OF DEEP TILLAGE

At present there are several brands of effective commercial strip tillage equipment on the market. When operating correctly, a strip-till operation should do the following:

1. Leave the row zone in a near-ready planting condition.

2. Provide deep tillage (subsoiling) to an appropriate soil depth, if desired.

3. **Not leave** large clods, sod clumps, or major surface holes or mounds that the planter would handle poorly, especially if the soil will be allowed to dry and harden before planting.

4. **Not leave** subsurface cavities in which there will be little rooting and that, during wet periods (when the soil may reach saturation and the cavities could act like a tile drain), could possibly cause root death.

Growers should keep in mind the differences between an effective strip-tillage operation, as described above, **versus** the actions and the potential advantages and disadvantages of deep-tillage tools, the most familiar of which is the subsoiler in its various configurations. On all commercial strip tillage equipment available today, the in-row subsoiler provides a major part of the row-zone soil preparation, combined with important actions of the accompanying devices, namely coulters, rolling baskets, and wheels. Therefore, depending on the depth of subsoiler operation, strip till rigs also usually perform deep tillage. Such in-row subsoiling often helps deepen the crop rooting pattern, especially if pan layers exist in the soil. You may wish to consult the publication *Subsurface Compaction and Subsoiling in NC—An Overview* (AG-353, North Carolina Cooperative Extension Service, 1985) for concepts of pan layers and deep tillage. Deep-tillage effects, however, can be minimal or even detrimental, depending on various aspects of soil properties, operational depth and travel speed, soil hardness or stickiness in the zone of the deep tillage, and the shape and size of the “point” of the deep tillage tool used.

Because of current grower interest, we have examined under on-farm conditions the effects of a typical subsoiler **in contrast with** those produced by the “no-till point” currently marketed by the DMI company. We have found that the large DMI point commonly leaves cavities in the soil at the depth of operation of the point. No such cavities were found in the zone of operation of the traditional in-row subsoiler. These DMI-point cavities were still very apparent near the end of the growing season in September after the tillage had been done in late March. The cavity typically is from 2 to 4 inches wide and about 1.5 inches high. Generally, no roots have grown directly through the cavity, although roots commonly pass around the sides. We do not yet have evidence that this tendency is detrimental to crop performance, although logically one would prefer to loosen a volume of soil in the prime zone of root growth, thus providing ideal soil physical conditions for crop root development. Attaining this objective would not include leaving a cavity zone unsuitable for root growth.

Some growers are interested in operating tools such as the DMI with winged points in a diagonal direction to the intended cotton rows, which certainly would reduce the area of such cavities directly under rows. Although this practice may be a useful compromise, it is likely to leave segments of row that would not benefit from this soil loosening, especially in specific fields where pan layers and soil hardness are actually limiting factors for root development.

AGRONOMIC CONSIDERATIONS

Research in North Carolina has shown that yields of no-till, and especially of strip-tilled cotton, are comparable to those of conventionally planted cotton if adequate stands and weed control are achieved. Yields of no-till cotton have sometimes exceeded those of conventionally planted cotton in dry years. The exception has been in wet-natured soils, where no-till cotton sometimes has not performed well. Year to year variability in rainfall and temperatures can make tillage decisions difficult at times. In some years, there is clearly an advantage to planting on a soft bed. In other years, however, there may be an advantage in flat-planting in no-till or reduced tillage systems. Growers are therefore encouraged to evaluate their tillage systems on a field by field basis, to ensure that little or no root obstruction or inhibition is occurring. Other factors also should be evaluated, such as the use of an in-furrow fungicide and starter fertilizer. Modifications to cover crop establishment and tillage should be made after careful evaluation of tillage across multiple years and environments.

The soil temperature under a good cover-crop residue generally will be 2°F to 4°F cooler than under bare soil. In addition, the soil may be more moist. The cooler and wetter environment may not be as conducive to seed germination and can contribute to seedling disease development. Plant conventional cotton first, allowing time for the soil to warm in no-till fields (see the discussion of soil temperatures in chapter 4, "Planting Decisions"). Also, because of the cooler and more moist conditions under a heavy cover crop residue, the chances of obtaining a response to an in-furrow fungicide are greater than under conventional tillage situations (see the discussion on in-furrow fungicides in chapter 9, "Disease Management in Cotton"). Also, especially in years when cool weather restricts DD-60s during the seedling development period, no-till and strip-till cotton are likely to show an economic response to starter fertilizer (see chapter 7, "Fertilization").

Research in North Carolina has shown that stands in no-till cotton average about 10 percent fewer plants than stands in conventionally planted cotton. This finding should not be a concern unless you are using a low seeding rate (see the discussion of seeding rate in chapter 4, "Planting Decisions").

When planting no-till cotton, adjust the planting depth carefully. Remember to plant ½-inch to 1-inch deep. Given the variability and hardness of no-till fields and the shallow depth of double-disk openers, it may be difficult to stride the line between adequately covering the seed and planting too deeply. Avoid planting when the soil is too wet for the seed furrow to be properly and consistently closed.

INSECT MANAGEMENT

In reduced or no-till cotton production, as in conventional tillage, likely damage from thrips will require the use of an at-planting, in-furrow insecticide. Because of the potentially cooler soils and resulting slower seedling growth, young plants may be subject to thrips populations over a somewhat longer period of time, putting a greater demand on the persistence of the at-planting insecticide. Alternatively, preliminary research suggests that thrips populations may be lower in reduced-till and no-till cotton. Monitoring or sampling for thrips in reduced-tillage cotton culture is the same as with conventional cotton production (see chapter 11, "Managing Insects on Cotton").

Preliminary research has shown the impact of insects such as cotton aphids, plant bugs, and late-season caterpillars in reduced-tillage cotton to be similar to that found in conventional cotton. In a limited number of experiments with strip-till cotton planted into wheat or cereal rye cover crops, some stand-reducing cutworm damage has been observed. Stand reductions in commercial cotton have been locally severe following the previously mentioned cover crops and behind corn, soybeans, and cotton in which winter annual weeds have served as a host for spring cutworms. Cutworms appear to be lower in cotton planted into hairy vetch or clover, but these covers are not commonly used in North Carolina. Because cutworms can persist at least 2 weeks following the application of a burndown herbicide, a waiting period of approximately 2½ weeks to 3 weeks is advised to reduce the possibility of damaging cutworm populations. If cotton fields have a history of cutworm damage, a broadcast or banded insecticide before or after planting may be appropriate. For example, the insecticide might be tank-mixed with a preemergence herbicide, or the insecticide alone might be sprayed into and up on the collar of the furrow in a T-band. Alternatively, if scouting reveals a stand reduction of 15 percent or more and an active population of cutworms (mostly "hiding" under soil clumps near cotton seedlings), then a banded or post-directed insecticide treatment is recommended. Cutworm-labeled pyrethroids or Lorsban 4E should provide adequate control. Grasshoppers and slugs may also be concerns in reduced-tillage systems.

DISEASE MANAGEMENT

Because conservation tillage often includes more variable seedbed conditions—including seed-soil contact, depth of coverage, zones of soil wetness, and cooler soil temperatures—it is important to use high-quality seed. Refer to chapter 4, "Planting Decisions," chapter 6, "Cotton Seed Quality and Planting Decisions," and chapter 9, "Disease Management in Cotton," for further information on these management concerns.

WEED MANAGEMENT

Most of the same weed-control techniques of conventional cotton culture are applicable to cotton produced with conservation tillage, with the exception of broadcast preplant-incorporated herbicides and most forms of cultivation. Chapter 10, "Weed Management in Cotton," gives key information on these topics.

14. SPRAYER CALIBRATION

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The performance of any pesticide depends upon many things, not the least of which is proper application at the correct rate. Failure to apply the correct rate uniformly can lead to poor pest control, crop injury, or unnecessary expense.

Every sprayer should be thoroughly calibrated before the first use of the season, and the calibration should be checked periodically during the season. In addition, the sprayer should be recalibrated every time nozzles, pressure, or travel speed is changed.

BEFORE CALIBRATION

Remove nozzles and strainers, including in-line strainers. Using a soft brush, wash nozzles and strainers in soapy water. Be sure to remove all deposits. Do not clean nozzles with any hard object (such as a knife or wire) because this will destroy the nozzle.

Thoroughly wash out sprayer and flush lines using a strong detergent or commercial tank cleaner. Check hoses and connections for leaks or signs of aging or damage. Replace defective hoses. Check components such as the pressure gauge, pressure relief/regulating valve, control valves, and agitator. Replace defective parts.

Select proper size and type of nozzle for the particular pesticide application planned. Consult nozzle manufacturers' catalogs or pesticide labels for guidance. Replace nozzles at least once a year. If the sprayer is used on a large acreage, nozzles may need replacing more frequently. Remember that brass nozzles wear more quickly than stainless steel or ceramic nozzles.

Make sure every nozzle on the sprayer is the same type and size (an exception may be hooded sprayers; see discussion below). Then check for proper spray pattern. Replace nozzles that do not produce the proper pattern. Next, check for uniformity of nozzle output. This check needs to be done even if new nozzles are installed.

To check for uniformity of output, partially fill sprayer with clean water. Adjust pressure to the level desired during the spraying operation. Catch and measure output from each nozzle separately for a given length of time. Replace any nozzle having an output of 10 percent more or less than the average of all nozzles.

CALIBRATION PROCEDURE

The procedure uses the equation below.

$$GPA = \frac{(GPM)(5940)}{(MPH)(W)}$$

GPA = gallons per treated acre
GPM = gallons per minute
MPH = travel speed, miles per hour
W = effective coverage per nozzle, inches

Step 1. Determine effective coverage per nozzle, or W.

W = nozzle spacing for broadcast application
W = band width when banding with one nozzle per band
W = band width divided by number of nozzles per band if banding with more than one nozzle per band

Step 2. Determine travel speed.

Measure off a distance of at least 200 feet in a field with surface conditions similar to fields to be sprayed. Engage any equipment to be used during the actual spraying operation (such as a disk or planter), choose the gear and throttle setting you plan to use during actual spraying, and determine the time required to drive the designated distance. You can improve your accuracy by doing this several times and taking the average.

$$MPH = \frac{(\text{feet traveled})(60)}{(\text{seconds to travel})(88)}$$

Step 3. Determine nozzle output.

Partially fill the tank with the desired liquid carrier (water or fluid fertilizer), but do not add pesticide. Adjust the pressure to the level that will be used during the actual spraying operation. Catch the output from several nozzles separately for one minute. Average the output over nozzles. It is best to catch the output as ounces per minute (OPM) and then convert to gallons per minute (GPM).

$$GPM = \frac{OPM}{128}$$

Step 4. Determine sprayer output, as gallons per treated acre (GPA).

$$\text{GPA} = \frac{(\text{GPM})(5940)}{(\text{MPH})(\text{W})}$$

Step 5. Determine amount of pesticide to add to tank.

$$\text{Amount to add} = \frac{(\text{pesticide rate per acre})(\text{gallons spray solution})}{\text{GPA}}$$

EXAMPLES

Broadcast Application: Preplant, Preemergence, or Postemergence Overtop

Assume you plan to broadcast 1.0 pint per acre of Reflex as a preemergence application. Your sprayer has nozzles mounted 19 inches apart along the boom, hence W = 19. The tank holds 240 gallons. It takes 20 seconds to drive 200 feet. You catch an average nozzle flow of 42 oz per minute (OPM).

$$\text{MPH} = \frac{(\text{ft})(60)}{(\text{sec})(88)} = \frac{(200\text{ ft})(60)}{(20\text{ sec})(88)} = 6.82$$

$$\text{GPM} = \frac{\text{OPM}}{128} = \frac{42}{128} = 0.3281$$

$$\text{GPA} = \frac{(\text{GPM})(5940)}{(\text{MPH})(\text{W})} = \frac{(0.3281)(5940)}{(6.82)(19)} = 15.04$$

$$\text{Amount to add} = \frac{(\text{pesticide rate per treated acre})(\text{gallons spray solution})}{\text{GPA}}$$

$$\text{Amount to add} = \frac{(1\text{ pt per treated acre})(240\text{ gal solution})}{15.04\text{ gal per acre}} = 15.96\text{ pt}$$

Banded Application Using One Nozzle Per Row: Preemergence or Postemergence Overtop

Assume you plan to apply Cotoran behind the planter at the broadcast rate of 1 quart per acre. You want to make a 14-inch band of Cotoran over the row using a single nozzle per band. In this case, W = 14. Your cotton is planted on 30-inch rows. The tank holds 240 gallons. It takes 28 seconds to drive 200 feet. You catch an average nozzle ouput of 26.5 oz per minute (OPM).

$$\text{MPH} = \frac{\text{(ft)(60)}}{\text{(sec)(88)}} = \frac{\text{(200 ft)(60)}}{\text{(28 sec)(88)}} = 4.87$$

$$\text{GPM} = \frac{\text{OPM}}{128} = \frac{26.5}{128} = 0.2070$$

$$\text{GPA} = \frac{\text{(GPM)(5940)}}{\text{(MPH)(W)}} = \frac{(0.2070)(5940)}{(4.87)(14)} = 18.03 \text{ This is gallons per treated acre.}$$

$$\text{Amount to add} = \frac{\text{(pesticide rate per treated acre)(gallons spray solution)}}{\text{GPA}}$$

$$\text{Amount to add} = \frac{\text{(1 qt per treated acre)(240 gal solution)}}{\text{18.03 gal per acre}} = 13.31 \text{ qt}$$

NOTE: When banding, always think of application rates in terms of "rate per treated acre," which is the rate given on labels. Obviously, you are not treating the whole acre, hence the pesticide rate per planted acre will be less. But, you have calibrated your sprayer output on the basis of "gallons per treated acre," and you want to calculate the amount of pesticide to add to the tank on that same basis.

Banded Application Using Two Nozzles Per Row: Postemergence-directed

Assume you plan to direct Caparol in a 16-inch band under the cotton. Your cotton is planted on 36-inch rows, you have two nozzles per row on your directed sprayer, and your sprayer tank holds 250 gallons. In this case, W = 8. The Caparol label suggests 1 quart per treated acre. It takes 25 seconds to drive 200 feet. You catch an average nozzle output of 19 oz per minute (OPM).

$$\text{MPH} = \frac{\text{(ft)(60)}}{\text{(sec)(88)}} = \frac{\text{(200 ft)(60)}}{\text{(25 sec)(88)}} = 5.45$$

$$\text{GPM} = \frac{\text{OPM}}{128} = \frac{19}{128} = 0.1484$$

$$GPA = \frac{(GPM)(5940)}{(MPH)(W)} = \frac{(0.1484)(5940)}{(5.45)(8)} = 20.22$$ This is gallons per treated acre.

$$\text{Amount to add} = \frac{\text{(pesticide rate per treated acre)(gallons spray solution)}}{\text{GPA}}$$

$$\text{Amount to add} = \frac{\text{(1 qt per treated acre)(250 gal solution)}}{\text{20.22 gal per acre}} = \text{12.36 qt}$$

NOTE: When banding, always think of application rates in terms of “rate per treated acre”, which is the rate given on labels. Obviously, you are not treating the whole acre, hence the pesticide rate per planted acre will be less. But, you have calibrated your sprayer output on the basis of “gallons per treated acre,” and you want to calculate the amount of pesticide to add to the tank on that same basis.

Hooded sprayers

Hooded sprayers can be a challenge to calibrate, depending upon the particular design and how one intends to use them. Hooded sprayers are relatively simple to calibrate if one is using them to apply herbicides only to the row middles or only directed under the cotton row. In that case, one would follow the procedures previously outlined for calibrating a banded application.

The original Redball hoods (Model 410 Conservation Spray Hoods) typically had three nozzles under the hood and one nozzle on either side of the hood directing spray into the row. The later “layby” or “dolphin nose” hoods (Redball model 420 Lay-By Spray Hoods) have one nozzle under the hood and one mounted into either side of the hood and directed under the row. Many operators block the nozzles mounted into the sides of the “layby” hoods and mount an adjustable post-directed nozzle on each rear corner of the hood. The newest version of spray hoods is the Willmar Model 915. It has three nozzles mounted under the row, and a kit can be purchased to mount a nozzle on the back of either side of the hood to direct under the row. If using adjustable post-directed nozzles spraying under the cotton row, make sure the patterns produced by the two nozzles overlap sufficiently under the row to provide uniform coverage across the band.

Any of the above types of hoods can be plumbed so that the nozzle or nozzles under the hood are on a separate system from the nozzles directing into the row. This technique allows one to apply different chemicals in the row middle from what is directed into the row. In that case, one would need to calibrate for each system independently. One would follow the previously described procedures for calibrating banded applications in the row middles and repeat the process for the directed spray.

When using the “layby” type hoods to apply the same chemical under the hood and directed into the cotton row, it is critical that one selects a lower output nozzle for directing under the row compared with the single nozzle spraying under the hood. If all nozzles are the same size, and one tries to calibrate based on average nozzle output, there will be a much higher than intended herbicide rate in the directed band and a lower than intended rate in the row middles. This rate difference may result in cotton injury or inadequate control in the row middles. For example, if one is covering 28 inches with the single nozzle under the hood and directing a 14-inch band under the row using two nozzles, the effective coverage per nozzle under the hood is 28 inches and the effective coverage per nozzle in the row is 7 inches. If the same size nozzle is used both under the hood and directed into the row, the application rate in the cotton row will be four times greater than the rate in the row middle.

As an example of how to calibrate a hooded sprayer, assume your rig has three nozzles spraying under the hoods and two nozzles directing into the row and you have 36-inch rows. Your sprayer is plumbed to apply separate herbicides under the hoods and directed under the row. Assume the area being effectively covered under the hoods is 27 inches (hence W = 9) and you are making a 12-inch band under the row (W = 6). Your tractor has two 200-gallon saddle tanks. You intend to apply 2.0 pints Direx plus 3.0 pt Gramoxone under the hood, and 1.25 pounds of Suprend plus 2.5 pt of MSMA under the row. You will need to calibrate under the hood and under the row separately. It takes 44.5 seconds to drive 300 ft. For the nozzles under the hood, you catch an average of 24 ounces per minute. For the nozzles directing into the row, you catch an average of 20.5 ounces per minute.

Under the hood:

$$\text{MPH} = \frac{(\text{ft})(60)}{(\text{sec})(88)} = \frac{(300\text{ ft})(60)}{(44.5\text{ sec})(88)} = 4.60$$

$$\text{GPM} = \frac{\text{OPM}}{128} = \frac{24}{128} = 0.1875$$

$$\text{GPA} = \frac{(\text{GPM})(5940)}{(\text{MPH})(\text{W})} = \frac{(0.1875)(5940)}{(4.60)(9)} = 26.90 \text{ This is gallons per treated acre.}$$

$$\text{Amount Direx to add} = \frac{(\text{rate per treated acre})(\text{gallons spray solution})}{\text{GPA}}$$

$$\text{Amount Direx to add} = \frac{(2\text{ pt})(200\text{ gal})}{26.90\text{ GPA}} = 14.9\text{ pt}$$

$$\text{Amount Gramoxone to add} = \frac{(3\text{ pt})(200\text{ gal})}{26.90} = 22.30\text{ pt}$$

Directed in the row:

$$\text{GPM} = \frac{\text{OPM}}{128} = \frac{20.5}{128} = 0.1602$$

$$\text{GPA} = \frac{(\text{GPM})(5940)}{(\text{MPH})(\text{W})} = \frac{(0.1602)(5940)}{(4.60)(6)} = 34.5 \text{ This is gallons per treated acre.}$$

$$\text{Amount Suprend to add} = \frac{(\text{rate per treated acre})(\text{gallons spray solution})}{\text{GPA}}$$

$$\text{Amount Suprend to add} = \frac{(1.25 \text{ lb})(200 \text{ gal})}{34.5 \text{ GPA}} = 7.25 \text{ lb}$$

$$\text{Amount MSMA to add} = \frac{(2.5 \text{ pt})(200 \text{ gal})}{34.5 \text{ GPA}} = 14.5 \text{ pt}$$

15. COTTON CLASSIFICATION

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Samples are taken from each North Carolina bale of cotton at the gin and sent to the United States Department of Agriculture–Agriculture Marketing Service (USDA–AMS) Cotton Classing office in Florence, South Carolina. These samples give cotton buyers information about the quality of the cotton the growers have produced. Producers should understand the classing system, as many aspects of cotton quality can be influenced by management decisions. Most of the information below is taken from the USDA publication *Cotton Classification Results*, which is available through the USDA–AMS, Cotton Division, 3275 Appling Road, Memphis, TN 38133.

The high volume instrument (HVI) classification system consists of the classer's judgment on color grade, leaf grade, and extraneous matter (if any), plus instrument measurements for fiber length, micronaire, strength, color, trash, and length uniformity.

Most classification data are provided to the industry by telecommunications, computer tapes, diskettes, and computer punch cards. In order to provide classification data for individual bales, the incoming bale identification tag must meet certain requirements, which are discussed below. For ease of explanation, the Universal Classification Data Format is used as an example for explaining the various quality measurements.

USDA—AMS COTTON DIVISION UNIVERSAL CLASSIFICATION DATA FORMAT

On the next page is a list of the quality parameters measured at the classing office and the corresponding column where you will find each quality parameter listed. This information applies to all methods of data dissemination offered by the Cotton Division. Columns 36, 46, 55, 58, and 62 are left blank intentionally.

Gin Code Number (Columns 1-5)
The gin code number is composed of five digits. The first two digits denote the classing office, and the last three digits identify the gin. The local classing office assigns this code number and can provide codes for any gin.

Gin Bale Number (Columns 6-12)
The seven-digit bale numbers are assigned by the gin. A bar-coded bale identification tag, preprinted with the gin code number and gin bale number, is placed between the two halves of the sample for identification purposes. The classing office scans the bar codes to enter the bale identification into its computer before classing the sample.

Table 16-1. USDA-AMS Cotton Division

UNIVERSAL CLASSIFICATION DATA FORMAT	
FIELD NAME	**COLUMN**
Gin Code Number	1–5
Gin Bale Number	6–12
Date Classed	13–18
Module, Trailer, or Single Bale	19
Module/Trailer Number	20–24
Bales in Module/Trailer	25–26
Producer Account	27–29
Color Grade	30–31
Fiber Length (32nd)	32–33
Mike (Micronaire)	34–35
Strength	37–40
Leaf Grade	41
Extraneous Matter	42–43
Remarks	44–45
HVI Color Code	47–48
Color Quadrant	49
HVI Rd	50–51
HVI + b	52–54
HVI Trash Percent Surface	56–57
Fiber Length (100th)	59–61
Length Uniformity Percent	63–64
Upland or Pima	65
Record Type	66
CCC Loan Premiums and Discounts	67–71

Date Classed (Columns 13–18)
This is the date the bale was classed in the classing office.

Module, Trailer, or Single Bale (Column 19)
This one-digit code indicates whether the sample was out-turned as a single bale or came from a bale that was module/trailer averaged: Single bale = 0, Module = 1, Trailer = 2.

Module/Trailer Number (Columns 20–24)
A five-digit number identifies the module/trailer number assigned at the gin.

Bales in Module/Trailer (Columns 25–26)
A two-digit number identifies the number of bales in the module/trailer that were averaged to determine the value of all the bales in the module/trailer.

Producer Account (Columns 27–29)
The producer account number space is reserved for USDA use.

Color Grade (Columns 30–31)
The color grade that appears on the classification record is determined by the classer, based on the official color grade standards. Color refers to the gradations of whiteness and yellowness in the cotton. Codes that identify extraneous matter and special condition cotton are shown in the "Extraneous Matter" and "Remarks" sections. Producers can influence color by having good defoliation and by getting the crop harvested before wet weather damages fiber color. The codes that identify American Upland color grades are as follows:

Table 16-2. Color Grades of Upland Cotton

	White	Light Spotted	Spotted	Tinged	Yellow Stained
Good Middling	11*	12	13	—	—
Strict Middling	21*	22	23*	24	25
Middling	31*	32	33*	34*	35
Strict Low Middling	41*	42	43*	44*	—
Low Middling	51*	52	53*	54*	—
Strict Good Ordinary	61*	62	63*	—	—
Good Ordinary	71*	—	—	—	—
Below Ordinary	81	82	83	84	85

* Physical standards. All others are descriptive.

Special Condition Codes for Upland Cotton
96 – Mixture of Upland and Pima
97 – Fire Damaged
98 – Water Damaged

Fiber Length – **32nds** (Columns 32–33); **100ths** (Columns 59–61). The HVI system measures length in hundredths of an inch. Length (staple) is reported on the classification record in both 32nds and 100ths of an inch. Low staple length has become more of a problem in the Southeast. Growers should avoid varieties with low staple length. Cotton with low staple length and high micronaire is very hard to sell. Growers should totally avoid varieties with both low staple length and high micronaire.

Micronaire (Columns 34–35)
An airflow instrument is used in the HVI system to measure fiber fineness. The measurements, commonly referred to as micronaire or "mike" readings, are the same as those that have been provided for many years in cotton classification. Micronaire and maturity are highly correlated within a variety. High mike is often a problem in North Carolina in drought-stressed years, especially where defoliation is delayed past optimum timing. Growers should try to avoid planting high micronaire varieties in fields that often have significant drought stress.

Strength (Columns 37–40, Decimal in Column 39)
Fiber strength is influenced most by variety selection. In general, full-season varieties have higher strength than short-season varieties. The fiber strength measurement is made by clamping and breaking a bundle of fibers, with a 1/8-inch spacing between the clamp jaws. Results are reported in terms of "grams per tex" to the nearest 10th. A tex unit is equal to the weight in grams of 1,000 meters of fiber. Therefore, the strength reported is the force in grams required to break a bundle of fibers one tex unit in size. The following table shows some general descriptions of HVI 1/8-inch gauge-strength measurements in grams per tex.

Table 16-3. Fiber Strength Table

Descriptive Designation	HVI 1/8" Gauge Strength (grams per tex)
Weak	23 and below
Intermediate	24–25
Average	26–28
Strong	29–30
Very Strong	31 and above

HVI Rd (Columns 50–51)

HVI +b (Columns 52–54)
The HVI color measurements cover grayness and yellowness. *Grayness* (HVI Color Rd) indicates how light or dark the sample is, and *Yellowness* (HVI Color +b) indicates how much yellow color is in the sample. The Nickerson-Hunter cotton colorimeter color diagram on page 11 of *Cotton Classification Results* is based on current official standards for American Upland cotton and shows how these measurements are coded and how they relate to the color of the grade standards. Each color grade is subdivided into quadrants to denote color differences within a color grade for more precise measurements. This information is reported as a two-digit Color Grade Code and a single digit grade quadrant. The resulting three-digit number is derived by locating the intersection of the Rd and +b readings on the diagram.

The Nickerson-Hunter cotton colorimeter color diagram on page 12 of *Cotton Classification Results* is based on the official standards for American Pima cotton. Color grades shown in the chart are the one-digit color grades of American Pima. Two digits are shown on the classification record, the first digit being zero (0). Grade quadrants are not used for American Pima.

HVI Trash Percent Surface (Columns 56–57)
The two-digit trash code reported on the classification record is the percentage of the sample surface covered by trash particles as determined by a video scanner. For example, a reading of 04 indicates that trash particles cover 0.4 percent of the sample surface. Trash particles include extraneous matter such as grass, bark, etc. However, the classer will continue to identify samples containing extraneous matter. Table 16-4 illustrates the relationship of leaf grade to the percentage of the surface area measured by the HVI trashmeter for the 1993 crop.

Table 16-4. Relationship of Classer's Leaf Grade to HVI Trash Reading, 1993 Crop

Classer's Leaf Grade	HVI Trash Reading
1	1
2	2
3	3
4	4
5	6
6	8
7	11
8	15

Length Uniformity Percent (Columns 63–64)
Length uniformity is a two-digit number that is a measure of the degree of uniformity of fibers in a sample. The descriptive terms in Table 16-5 may be helpful in understanding the measurement results.

Table 16-5. Length Uniformity Percent

Descriptive Designation	HVI Length Uniformity
Very Low	Below 77
Low	77–79
Average	80
High	83–85
Very High	Above 85

Upland or Pima (Column 65)
The one-digit code indicates whether the sample is Upland or American Pima.

1 = Upland
2 = Pima

Record Type (Column 66)
The one-digit code gives the type of record, according to the following:

0 = Original, 1 = Review, 2 = Rework, 3 = Duplicate, 4 = Correction

CCC Loan Premiums and Discounts (Columns 67-71)
The five-digit code gives the CCC loan premium and discount points for Upland cotton.

Upland—Column 67 (+) if Premium, (-) if Discount
Columns 67–71 will be left blank if the quality is not eligible for loan.

16. COTTON TERMINOLOGY

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adulticide—A chemical, usually an insecticide, that is targeted toward the adult stage.

aphicide—An insecticide that is active against aphids.

beat cloth—A square (typically 3 feet by 3 feet, or 2.5 feet by 2.5 feet) or rectangular piece of usually light-colored cloth or synthetic sheeting (i.e., Tyvek material) with dowels at opposite ends; used to assess insect populations by catching them when plants are beaten or shaken over the device, which is normally unrolled and placed on the ground between rows. More recently, drop cloths made of black material are being sold due to the dark background offering more contrast in recognizing immature plant bugs (nymphs). Also called a shake cloth or ground cloth.

beet armyworm—(*Spodoptera exigua*) An armyworm species whose damage to cotton is characterized by leaf skeletonizing by early instars feeding in groups, often associated with webbing and frass. Later instar larvae may feed on squares and bolls and are difficult to control with insecticides; eggs are deposited in masses; adults are migratory and do not overwinter in the Carolinas.

beneficial arthropods—A general group of insects and their cousins (predatory mites and spiders) that either consume (predator) or live within (parasite) the host insect.

bloom tag—The dried brown cotton bloom that sticks to the tip (or, at times, off to one side) of the young boll; more frequent in dry weather; sometimes provides a refuge under which young bollworms or tobacco budworms develop protected from beneficial insects and insecticides. Inexperienced scouts sometimes tend to oversample young bolls having a bloom tag. The sampling of bloom-tagged bolls should be carried out in proportion to their percentage of the total boll population.

blooming out the top—A cotton growth state characterized by the presence of first-position blooms almost entirely in the upper canopy of the cotton plant. This occurrence may indicate premature cutout of the crop. Often called bumblebee cotton when this condition occurs abnormally early on short, stressed cotton.

blooms—Large, showy, off-white flowers that arise from buds (squares) and typically last only one day, becoming pinkish on the second and brown on subsequent days; they usually fall from the new, developing boll on days three to five. Cotton blooms are at times attractive sites for bollworm egg deposition, western flower and other thrips, and fall armyworms. Blooms in the tops of cotton plants (blooming out the top or bumblebee cotton) often indicate very dry weather or that the crop is cutting out.

boll weevil—(*Anthonomous grandis*) A small brownish to grayish weevil that survives the winter as an adult and invades cotton in the spring to infest one-third grown or larger cotton squares, causing fruit abortion via feeding punctures or egg punctures; completes life cycle within fallen squares in 2½ to 3 weeks. A major pest of cotton in North Carolina before the beginning of the Boll Weevil Eradication Program in 1978, which has successfully eliminated this pest. May undergo three to four generations per year in the Carolinas.

Bollgard II cotton—A cotton variety that has two "stacked" (or "pyramided") genes that each encode for the expression of separate endotoxins (*Bacillus thuringiensis*; Cry1Ac and Cry2Ab proteins) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms, compared to Bollgard.

bollworm—(*Helicoverpa zea*) The larval or caterpillar stage of the corn earworm moth. Typically North Carolina's most significant cotton pest, primarily infesting fruit (squares, blooms, and bolls). Undergoes three to four generations annually in the Carolinas, with the first two generations developing primarily in field corn (initial generation primarily on whorl stage corn and the second generation primarily on early ear stage corn) and the third on cotton, soybeans, peanuts, and other crops. Also called soybean podworm and tomato fruitworm, depending upon host.

bract—The three modified leaves at the base of the cotton fruit. Bracts typically surround developing squares, affording some protection to bollworms and other pests from beneficial insects and insecticides; must be opened to reveal developing square when monitoring fruit for damage.

brown stink bug— (*Euschistus servus*) A brownish, medium-sized member of the stink bug family (Pentatomidae) that usually undergoes a generation on hosts, such as wheat, corn and other grass species, before moving into cotton, often during boll formation. Feeding by adults and large nymphs with needle-like stylets, on bolls of all sizes, causes small, rounded, dark spots on the exterior carpel wall; feeding can transmit hardlock organism, resulting in unharvestable bolls and low-quality lint. Brown stink bugs are more difficult to control with pyrethroids than green stink bugs. This species' life cycle (egg to adult) typically takes 40 days.

calyx—Outer protective covering of the flower bud (square); the leaf-like green segment, also called sepals.

canopy—The foliage of a cotton crop; said to be closed when plant growth of adjacent rows closes over and shades row middles; direct sunlight penetration between rows constitutes an opened canopy.

carbamates—A class of chemicals, usually insecticides, that inhibits cholinesterase, resulting in unregulated nerve-ending activation and paralysis in insects (e.g., Temik, Sevin, Larvin).

carpal wall—The thick outer walls of the boll. If insects (e.g., bollworms, green stink bugs) penetrate the carpal walls, they may cause damage to locks (see definition) or may cause boll rot, translating into lost yield and/or lower lint quality.

caterpillar—The immature damaging stage of a butterfly or moth. Larva is the general term for immature stages of moths (caterpillars), flies (maggots), beetles (grubs), and others.

chloronicotinoid—A widely used class of insecticides that blocks nerve transmission in insects (i.e., imidacloprid and thiamethoxam). This chemical class is widely used to control thrips, cotton aphid, and plant bug, although several cases of resistance have been reported.

cotton aphid—(*Aphis gossypii*) The aphid species most commonly associated with outbreaks on cotton in the Southeast; has many generations per year and is often resistant to various classes of insecticides; typically subject to heavy mortality via predation and parasitism; also called the melon aphid.

cotyledon—In dicotyledonous plant species, the initial growth stage characterized by the presence of "seed leaves." These leaves were initially contained in the seed and provide food for seed germination.

cumulative threshold—The point at which consecutive scouting assessments of subthreshold levels of the same species justify treatment.

cutout—Final stage of cotton plant growth before boll opening; characterized by the predominance of more mature fruit, general absence of squares and blooms, and cessation of new terminal growth. According to more recent terminology, cotton is approaching cutout at five nodes above white bloom and is generally considered to be cutout at three nodes above white bloom. Cotton blooming out the top is considered cutout.

defoliant—A harvest-aid material applied to the cotton plant to accelerate leaf drop in preparation for harvest (see defoliation).

defoliation—The loss of leaves from the cotton plant; may be damaging and happen prematurely (e.g., soybean loopers consuming cotton plant leaves before cutout or leaf loss caused by a potassium deficiency) or naturally (the predictable loss of leaves of all deciduous plants).

egg—A single cell or ovum from an ovary; the first stage of an insect or mite; may be deposited singly (e.g., bollworm) or in a mass (e.g., European corn borer).

dessicant—A harvest-aid applied to the cotton plant that kills the leaves. This is undesirable in spindle harvesting systems and will result in high leaf grades.

European corn borer—(*Ostrinia nubilalis*) A pest of cotton in the Southeast where corn is planted, this boring caterpillar passes its initial two generations on corn, potatoes, wheat, and various weed species in North Carolina; the third and a partial fourth generation can be damaging to cotton, primarily because the pest bores into medium to large bolls and to a lesser extent into stems; female moths deposit small, fish-scale-like egg masses deep within the plant canopy and on the undersides of cotton leaves. Egg masses are difficult to find. In two-gene *Bt* cotton, European corn borer damage is essentially nonexistent.

fall armyworm—(*Spodoptera frugiperda*) A migratory species that does not overwinter in the Carolinas; larvae hatch from egg masses often deposited in the upper third of the cotton plant, frequently on the undersides of leaves but also in the terminal area; small larvae typically etch the bracts of medium and large bolls before penetrating the carpel walls, often at the base of the boll. Fall armyworm larvae are also often associated with blooms. Medium to large established larvae are difficult to kill with insecticides.

foliar feeding—On cotton: (1) leaf consumption, usually by caterpillars; (2) the feeding of nutrients, such as nitrogen-containing fertilizer, to the cotton plant via a liquid applied to the foliage.

frass—A term applied to insect feces, the shape of which is sometimes used in family-level or species-level identification; also called fecal pellets, droppings, or turds.

fruit—Refers to cotton squares (or flower buds), blooms, and bolls; reproductive parts of the plant. Cotton fruit is susceptible to a wide range of insect pests.

fruiting branch—Lateral branch of a cotton plant, typically arising from the fourth through eighth nodes and higher on the plant; has fruiting position at each node; sympodium or reproductive branch.

fruiting position—Any main stem, vegetative branch, or fruiting branch location on which fruit is either present or aborted.

fungicide—A material used to control or kill fungi.

green stink bug—(*Chinavia hilare*) A large green member of the stink bug family (Pentatomidae) that usually undergoes a generation on wild hosts, such as elderberry and wild cherry, before moving into cotton, often during boll formation. Feeding by adults and large nymphs with needle-like stylets, often on bolls of all sizes, causes small, rounded, dark spots on the exterior carpel wall; feeding can transmit hardlock organisms, resulting in unharvestable bolls and low-quality lint. This species' life cycle (egg to adult) typically takes 30 to 40 days.

herbicide—A material used to kill weeds. In cotton the material usually is characterized by (1) timing: "PPI" (prior to planting and incorporated), "pre" (prior to plant emergence from soil), and "post" (after plant emergence); or by (2) application type: "broadcast" (applied evenly over an area), “banded” (applied over a portion of the total area), or “directed” (targeted at a specific area), usually toward the base of the cotton plant.

insect growth regulator—A compound, either natural or synthetic, that influences insect growth and development (e.g., Dimilin affects boll weevil grub integument formation during shed, resulting in deformed pupae and adults or premature death). Often referred to by its acronym, IGR.

insecticide—A material that kills insects.

instar—Stage of nymph (e.g., stink bug) or larva (e.g., bollworm) between molts.

internode—The portion of the main stem between nodes; in cotton it is often used as an indicator of growth; i.e., a greater internode length indicates faster growth and the possible need of a growth regulator capable of slowing growth, such as Pix.

label—A legally binding document affixed to every pesticide container outlining the product’s constituents, amount of active ingredients, primary uses, precautions, and Worker Protection Standard (WPS) information.

larva—The immature stage of an insect with four distinct metamorphic stages (e.g., cabbage looper: egg, larva [caterpillar], pupa, and adult).

larvicide—A compound that kills the larval stage of insects.

layby—A final, typically post-directed herbicide application designed to eliminate or suppress weeds through harvest time.

Liberty Link cotton—A cotton variety that has been genetically altered to tolerate the herbicide Ignite (glufosinate).

licensed consultant—An individual licensed by the North Carolina Department of Agriculture and Consumer Services, who is trained to interpret information and make recommendations.

light trap—A device consisting of at least an ultraviolet light (which is attractive to several night-flying insects) and a collection container. Used to monitor the timing and relative abundance of selected insect species (e.g., bollworm, green stink bug, and tobacco hornworm moths).

lock—The major, individual, internal section of a cotton boll in which seed and lint development take place; four or sometimes five locks per boll are typical.

match-head square—Early stage of growth when the flower bud (excluding the outer bracts) reaches approximately the size of a large kitchen match head.

migratory—A term applied to an insect species that undergoes long-range movement, sometimes hundreds of miles (e.g., fall armyworms do not overwinter in the Carolinas but rely instead on annual, long-range, northward movement by consecutive generations "hopscotching" from the southern United States). It can also refer to shorter, more localized flights or transport (e.g., the migration of thrips from alternative hosts to cotton).

mites—A group of small, active, noninsect arthropods, some of which are predators of other mites and small insects (e.g., thrips); most species are plant feeding. The two-spotted spider mite (*Tetranychus urticae*) is the predominant mite on cotton in the Southeast, typically more of a problem under hot, dry conditions, and damages cotton plants by rasping mostly lower leaf cells; populations are often reduced by naturally occurring fungi, particularly under humid conditions.

miticide—A material that kills mites.

multipest threshold—The point at which the combined effects of subthreshold levels of two or more pests justify treatment.

naturalites—A class of fermentation products called spinosads derived from an ascomycetous fungus, which is active against Lepidoptera and selected members of other insect families and some mite species.

node—A point, usually along the main stem, at which lateral vegetative and fruiting branches arise.

nodes above cracked boll—Term applied to the number of main-stem nodes from the highest first position cracked boll to the node of the upper most harvestable boll (often used as a method of assisting with measurements of cotton readiness for defoliation).

nodes above white bloom—Term applied to the number of main-stem nodes from the last developed first-position white bloom to the plant terminal; used as a measure of plant growth (e.g., to assist in growth regulator assessments or as an index of degree of "cutout"). All plants will not have a first-position white bloom at a given time.

organophosphates—A class of organic, phosphorus-containing insecticides that inhibit cholinesterase, causing excess nerve activation, paralysis, and eventual death; some insecticides in this class with a high phosphorus content (e.g., methyl parathion) may delay cotton crop maturity if applied at an early stage; abbreviated OP.

overtop herbicide application—A herbicide application which is made over the top of the cotton canopy. These herbicides do not negatively impact, or only minimally affect, the growth of the cotton plant (e.g., glyphosate on Roundup Ready cotton, the ALS inhibitor Staple, and others).

ovicide—A material that kills the egg stage of an organism.

parasite—An organism that lives wholly off and often feeds within another organism (called a host); with most insect species, insect parasites usually kill their hosts and are referred to as parasitoids.

pheromone trap—A trap that uses either a natural or, more typically, a synthetic insect sex attractant pheromone; these traps are usually species specific.

pinhead square—In practice, this misnomer most often applies to match-head squares. Pinhead squares are just visible to the naked eye. This stage is about 21 days prior to the square blooming.

plant bugs—Small, active, dark-brown bugs with piercing-sucking mouthparts. Their immatures are bright-green. The mouthparts make tiny needle-like holes in small squares, causing darkening and abortion. At high population levels, terminal feeding may result in unusual upper growth (crazy cotton) and loss of apical dominance; late in the season, high levels of plant bugs can also damage larger squares, blooms, and small bolls. In the Southeast, the primary pest species is the tarnished plant bug, *Lygus lineolaris*.

plant growth regulator—A substance applied to cotton plants that affects growth or aging (e.g., Pix and Prep); abbreviated PGR.

plant map—A precise, prescribed manner of recording, or mapping, cotton plant growth that shows the location and stage of fruit by its position on each node of all vegetative and fruiting branches. Plant maps are often used to determine nodes above white bloom, nodes above cracked boll, and fruit retention and to compartmentalize and compare fruit retention on selected horizontal or vertical zones of the cotton plant. Modified mapping systems are available that focus on particular vertical zones of cotton, such as first position only.

point sampling—A scouting method that relies on randomly selecting a prescribed number of sites or points within a cotton field for intensive scouting of a predetermined number of plants or feet of row (best suited to uniform fields).

postemergence-directed—Herbicide placement after seedling emergence directed to the base of cotton plants; better control if cotton has grown significantly taller than weeds (e.g., Bladex).

postemergence over the top—Herbicides applied directly over the canopy of both cotton and weeds; sometimes represents a salvage treatment following inadequate PPI or preemergence weed control; some compounds may cause maturity delays and yield reductions (e.g., Cotoran).

predator—An organism that kills and consumes another (its prey); several small predator insects can provide significant natural control of several pests.

preemergence—A term most often referring to broadleaf herbicides applied at or after planting but before seedling emergence; "pre" herbicides (e.g., Zorial).

preplant incorporated—Refers mostly to grass and small-seeded broadleaf herbicides (but also some other weed species such as nutsedge) applied and incorporated before planting; PPI herbicides (e.g., Treflan).

pupa—The compact, often protected, resting stage of an insect preceding the adult stage (bollworms overwinter in the pupal stage under the soil surface).

pyramided genes—See stacked genes.

pyrethroids—A class of insecticides characterized by very low mammalian toxicity and high insect control at low usage rates.

random sampling—A scouting method that relies on continuous inspections throughout most of a cotton field; better suited for regions with variable soils within fields.

rank—A term signifying tall, excessive cotton growth; often a result of late planting, excessive nitrogen fertilizer, fertile soils, or excessive moisture. Rank growth often renders cotton plants more attractive and susceptible to late-season insects, more susceptible to boll rot, and more difficult to defoliate.

refugia—In cotton insect management, an area used to maintain the production of susceptible insect populations. A refugia is a crop or host area that is left untreated with an insecticide or type of technology so that adults that are resistant to the chemical, chemical class, or technology in question will have a high probability of mating with the higher number of refugia-produced, susceptible adults, thus producing susceptible offspring. For example, to preserve the effectiveness of *Bt* single-gene cotton, a specified acreage of non-*Bt* cotton at one time had to be set aside to produce enough *Bt*-susceptible adult bollworms and tobacco budworms to mate with a high enough proportion of the *Bt*-produced resistant individuals to maintain a population of budworms and bollworms susceptible to *Bt* cotton.

resistance—The inherited development of insect, weed, or disease biotypes that are tolerant to an insecticide, fungicide, or herbicide, respectively, which formerly provided control of the particular pest species. For example, biotypes of Palmer amaranth have developed that survive high rates of glyphosate.

restricted entry interval—The mandatory period of time a person must wait between application of a chemical and entry to the treated area.

Roundup Ready—Trademark term applied to varieties that have been genetically altered to be tolerant to the herbicide glyphosate.

sample—The portion of a population collected in a prescribed manner upon which a judgment is made about the entire population.

scout—An individual trained to collect information about cotton insect and plant populations; scouts are not responsible for interpreting data or providing recommendations.

scouting—The procedures followed by a scout.

skeletonizing—A type of insect damage characterized by insect feeding on leaf areas between veins; it can result in a lacy appearance to the leaf.

soybean looper—(*Pseudoplusia includens*) A light-green, defoliating caterpillar; migratory adults overwinter in the southern United States or Caribbean basin and typically arrive in the Carolinas in late summer or fall.

square—The flower bud of a cotton plant with a central corolla containing the pollen anthers and sepals and surrounded by three (or sometimes four) bracts; squares are often a preferred site of insect feeding (e.g., plant bugs, boll weevils, bollworms).

square retention—The proportion of squares, usually expressed as a percentage, retained by the cotton plant (often employed early in the growth of a cotton plant as an index of plant development).

stacked—Using two or more genes in a cotton variety for expression of similar characteristics (Bollgard II will use two *Bt* genes to express different endotoxins for caterpillar control) or dissimilar characteristics (Bollgard gene plus Roundup Ready gene for herbicide tolerance to Roundup herbicide).

stacked genes (or pyramided genes)—Two or more genes inserted into the plant's DNA that express similar (though enhanced) activity (e.g., two genes that encode for separate *Bacillus thuringiensis* endotoxin expression in the same variety, as in Bollgard II, WideStrike, and TwinLink varieties) or two genes that express different activities in the same variety (such as caterpillar resistance plus Roundup Ready glyphosate tolerance).

starter fertilizer—Fertilizer placed close to the seed, usually at planting; also called "pop-up" fertilizer. Because cotton is very sensitive to ammonia, care should be taken to place the starter fertilizer 2 inches from the seed.

sweep net—A sturdy net composed of a 15-inch (standard size) rigid wire support and a heavy-duty cloth bag used to "sweep" across the upper canopy of cotton plants to assess insect populations.

systemic—A pesticide that is taken up through the roots or leaf tissues into the cells of the cotton plant (as opposed to remaining on the surface), often in concentrations high enough to cause a biological change (e.g., a systemic might be an at-planting soil insecticide taken up by cotton seedling roots and transported through the plant's vascular system to suppress or kill leaf-feeding thrips, or it might be Roundup herbicide absorbed into the vascular system of weeds and translocated to the root zone in high enough concentrations to kill the weed).

terminal—The dominant, upper main-stem part of a cotton plant containing three to four expanding leaves and developing squares; if they are all retained, the number of squares typically is identical to the number of leaves; also called "apex."

threshold—The point at which an action is taken; often applied to insects. (Most thresholds are action thresholds; an action is taken when a level or number of eggs or caterpillars is reached. It can also be an economic threshold, which takes the commodity value and treatment cost into consideration.)

thrips—Tiny, active insects of the order Thysanoptera, which move in high numbers primarily into seedling cotton, often because their alternative hosts are drying up.

TwinLink—A cotton variety that has two "stacked" (or "pyramided") genes that each encode for the expression of separate endotoxins (*Bacillus thuringiensis*; Cry1Ab and Cry2Ae proteins) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms, compared to the former Bollgard varieties.

tobacco budworm—(*Heliothis virescens*) A caterpillar pest of primarily squares and bolls; a close relative of the corn earworm. It undergoes three to four generations annually and often is the predominant species of the bollworm/budworm complex in June in the Carolinas. Mid-South populations of tobacco budworms have developed resistance to all major classes of insecticides.

transgenic cotton—Cotton that has been genetically altered by recombinant DNA techniques to express tolerance to either herbicides (e.g., Roundup Ready and LibertyLink) or insect pests (e.g., Bollgard II against tobacco budworms).

vegetative branch—Lateral branch on a cotton plant that does not have a fruit at each node; fruiting branches, however, can develop from vegetative branches. Vegetative branches have a terminal and often develop fruiting branches, especially under low plant populations.

vegetative growth—General term for undesirable cotton plant growth, typified by lack of fruit; often tall and rank.

wart—A small, typically round, area of callous growth on the inside of the boll wall associated with stink bug or plant bug feeding. Warts are usually counted as damage in scouting assessments.

weed map—A simple diagram, typically developed in the fall, of a field or field portion showing the location of predominant, economically important weeds; used in planning weed management programs.

whitefly—A small, white-winged insect with piercing-sucking mouthparts; damages cotton both directly via its sap-feeding and indirectly via voiding honeydew, resulting in "sticky cotton," a ginning and milling problem.

WideStrike cotton—A cotton variety that has two “stacked” (or “pyramided”) genes that each encode for the expression of separate endotoxins (*Bacillus thuringiensis*; Cry1Ac and Cry2Ab) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms when compared to Bollgard.

WideStrike 3 cotton—A cotton variety that has three “stacked” (or “pyramided”) genes that each encode for the expression of two endotoxins and a single exotoxin (*Bacillus thuringiensis*; Cry1Ac and Cry2Ab and Vip3A) that are effective against a wide spectrum of caterpillar pests and offer enhanced activity against bollworms when compared to Bollgard.

windowpaning—See skeletonizing.